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ENGINEERING:

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30th July, 1918. M 314

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A NEW THEORY OF THE STEAM TURBINE.

By Harold Medway Martin, Wh.Sc., A.C.G.I.

(*Continued from page* 55.)

It will be seen from the discussion in the previous article that the adiabatic heat drop under different conditions cannot be taken as proportional to the actual effective thermo-dynamic head. Where the superheat is high the reheat factor is also high, and *vice versa*. If the superheat be maintained during half the total steam path through the turbine the steam will, during this period, benefit by a higher reheat factor than when it passes as wet steam through the remainder of the turbine. It will now be shown that this consideration is not of itself sufficient to rationalise the known values of the superheat corrections.

The point at which different degrees of initial superheat are lost can be determined in the following way. Assume, for example, that the initial pressure is 180 lb. absolute, and that the hydraulic efficiency of the turbine is 70 per cent. Suppose the superheat to be lost at, say, 80 deg. C., the volume of the steam is then 54.596 cub. ft. per lb. (Callendar) and its pressure is 6.8627 lb. per square inch. The initial pressure being 180 lb. absolute, we have

$$x = \frac{p_1}{p_2} = \frac{180}{6.8627}$$

If ρ be the ratio of the final volume to the initial volume, then, since the expansion follows the law $p\,V^{\lambda} = \text{constant}$, we have $\rho = x^{\frac{1}{\lambda}}$.

The value of $\frac{1}{\lambda}$ is given (page 53 *ante*) by the relation

$$\frac{1}{\lambda} = 1 - 0.23077\,\eta = 1 - 0.23077 \times 0{\cdot}7 = 0.8385$$

Whence:

$$\rho = \left[\frac{180}{6.8627}\right]^{0{\cdot}8385} \quad \text{and} \quad V_1 = \frac{V_2}{\rho} = 3{\cdot}528 \text{ cub. ft. per lb.}$$

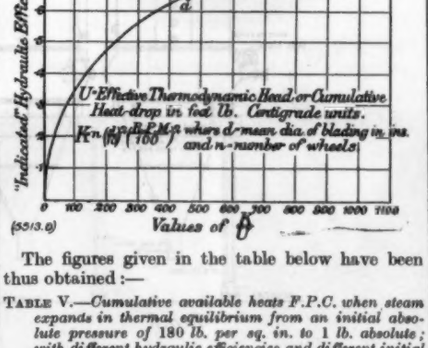
Reference to Callendar's table shows that steam at 180 lb. absolute, with this specific volume, has a temperature of 331.6 deg. C., corresponding to a superheat of 142.1 deg. C., or 255.8 deg. F. By determining a number of values in this way and plotting the results as curves, the temperature at which any stated initial superheat is lost can be determined. The figures tabulated below have thus been obtained:—

Table IV.—*Approximate Temperature (Centigrade) at which superheat is lost for different hydraulic efficiencies η when the initial pressure is 180 lb. absolute.*

Hydraulic Efficiency η.	Original Superheats.						
	0	50 deg. F.	100 deg. F.	150 deg. F.	200 deg. F.	250 deg. F.	300 deg. F.
	Deg. C.	Deg. C.	Deg. C.	Deg. C.	Deg. C.	Deg. C.	Deg. C.
0·5	189·5	133·9	94·0	64·5	45·0	27·4	—
0·6	189·5	149·9	117·4	93·9	75·0	59·0	46·2
0·7	189·5	157·3	133·3	112·5	95·7	81·8	69·7
0·8	189·5	163·7	142·5	125·0	110·4	98·0	86·9

With the temperatures given in the above table we can calculate the total effective thermodynamic head or, to use Professor Goudie's term, the cumulative heat, which becomes available in a turbine when expanding steam from 180 lb. absolute to 1 lb. absolute with different hydraulic efficiencies, the steam being supposed to be in thermal equilibrium throughout. Suppose, for example, that in the initial condition the superheat is 150 deg. F. and that the hydraulic efficiency is 0·6. Then from the table it appears that the superheat will be lost when the temperature of the expanding steam falls to about 93·9 deg. C. From Callendar's tables we find that the total heat of saturated steam at this temperature is 636·81 ft.-lb. Centigrade units, whilst the total heat of the steam in its initial state was 715·29 deg. ft.-lb. Centigrade units. The difference between the figures is 78·48 ft.-lb. Centigrade units, and this represents the useful work done. Hence, as the hydraulic efficiency is 0·6, the cumulative heat or effective thermodynamic head expended in the superheated field is $\frac{78{\cdot}48}{0{\cdot}6} =$ 130·80 ft.-lb. Centigrade units. The remainder of the expansion down to the final pressure of 1 lb. per square inch is, on our present hypothesis, effected in conditions of thermal equilibrium. The value of the adiabatic heat drop u_s for this expansion from the pressure of steam saturated at 93·9 deg. F. can be found in the usual way, either from the tables or by measurement from the steam chart, Plate I *ante*. From Callendar's tables we find that u_s in the present case is 85·98 ft.-lb. Centigrade units. The pressure of steam saturated at 93·9 deg. C. is 11·76, so that x, the ratio of initial to final pressure in this expansion, is $\frac{11{\cdot}76}{1}$, and from Table III, page 54 *ante*, the corresponding reheat factor is about 1·0309. Hence the cumulative heat U_s expended during this part of the expansion is $U_s = R\,u_s = 1{\cdot}0309 \times 85{\cdot}98 = 88{\cdot}63$ ft.-lb. Centigrade units. Hence the total accumulative heat $U = U^1 + U_s = 130{\cdot}80 + 88{\cdot}63 = 219{\cdot}43$ ft.-lb. Centigrade units. The value of u, the adiabatic heat drop for the whole range of expansion, is 201·66 ft.-lb. Centigrade units, so that the efficiency ratio corresponding to the hydraulic efficiency of 0·6, is $\frac{219{\cdot}43}{201{\cdot}66} \times 0{\cdot}6 =$ 0·6529, and the average reheat factor for the whole range of the expansion is 1·088.

Fig. 4. "INDICATED" HYDRAULIC EFFICIENCY OF IMPULSE TURBINES IF STEAM EXPANDS IN THERMAL EQUILIBRIUM THROUGHOUT.



The figures given in the table below have been thus obtained:—

Table V.—*Cumulative available heats F.P.C. when steam expands in thermal equilibrium from an initial absolute pressure of 180 lb. per sq. in. to 1 lb. absolute; with different hydraulic efficiencies and different initial superheats.*

Hydraulic Efficiency η.	Initial Superheats.						
	0 deg. F.	50 deg. F.	100 deg. F.	150 deg. F.	200 deg. F.	250 deg. F.	300 deg. F.
0·5	201·3	207·2	216·2	226·9	238·9	251·1	262·4
0·6	197·4	203·5	210·3	219·4	229·6	240·4	251·4
0·7	194·1	199·2	206·7	214·2	222·6	232·9	241·3
0·8	190·7	196·3	202·5	209·3	216·9	228·5	233·6
1·0	184·1	189·5	195·4	201·7	208·2	215·0	222·0

To determine from this table the theoretical steam rate for a turbine working with different superheats a correction is required because increases in the effective thermodynamic head change the ratio of blade speed to steam speed.

This correction can be effected by means of the curve plotted in Fig. 4 on the assumption that thermal equilibrium was maintained throughout the whole expansion. In this curve the "indicated" hydraulic efficiency of a number of impulse turbines is plotted against $\frac{K}{U}$ where:

$$K = n\left(\frac{d}{10}\right)^2 \left(\frac{\text{R.P.M.}}{100}\right)^2$$

and U denotes R u where u is the adiabatic heat drop. In the above expression for K, the number of stages is represented by n, whilst d denotes the mean diameter of the blading. Since the average velocity of the steam is proportional to $\sqrt{\frac{U}{n}}$ the expression $\sqrt{\frac{K}{U}}$ is proportional to the ratio of blade speed to steam speed. According to the ordinary view the indicated hydraulic efficiency should give a parabola when plotted against $\sqrt{\frac{K}{U}}$ and consequently the curve in Fig. 4 should be an ellipse. The points lie badly on an ellipse, however, and the curve shown has been sketched in freehand. As will be shown later a much better agreement between the curve and the experimental figures is obtained when the theory that the steam expands in thermal equilibrium is abandoned. In point of fact the result represented by f, the last point plotted on the diagram, was obtained with a turbine which was certainly over-speeded. Yet, according to the ordinary theory on which the plot is based, its efficiency is apparently the highest of the lot. The turbines varied greatly in design and size, and it was therefore essential to correct the actual test figures for disc friction, fan action, gland and bearing losses. For the disc friction and fan action Kerr's formula (Engineering, August 22, 1913) page 268, was used. The energy wasted in journal friction was calculated by the formula:

$$\text{Kw. wasted} = \frac{1}{4}\left(\frac{d}{10}\right)^2 \left(\frac{l}{10}\right) \frac{\text{R.P.M.}}{100}.$$

where d denotes the journal diameter in inches and l its length in inches. Thrust block friction was estimated from the formula

$$\text{HP wasted} = \frac{N\,b}{8}\left(\frac{\bar{d}}{10}\right)^2 \frac{\text{R.P.M.}}{100}$$

where N denotes the number of collars and $\bar{d}$ the mean diameter of the collars and b their radial depth, both taken in inches. Water gland friction was estimated from the formula:

$$\text{Impeller friction HP} = \frac{1}{1000}\left(\frac{d}{10}\right)^3 \left[\frac{d}{10}\frac{\text{R.P.M.}}{100}\right]^{2\cdot6}$$

Labyrinth packing losses were estimated from the usual dummy leakage formulæ.

The test figures gave the brake efficiency ratio, and this was by means of the above corrections reduced to indicated efficiency ratios. The initial and final states of the steam being known, it was possible to calculate, by the method explained earlier in this article, the efficiency ratios which would correspond to such hydraulic efficiencies as 0·5, 0·6, 0·7 and 0·8, and by interpolation the hydraulic efficiency corresponding to the observed efficiency ratio was then obtained.

At the time Mr. Baumann published his correction curves a high value for the hydraulic efficiency (thus calculated) of an impulse turbine was 0·7. This, it will be seen from the curve, corresponds to a value of $\frac{K}{U}$ equal to 580. If we assume that this was the value of η with steam superheated to 150 deg. F., in which case the effective thermo-dynamic head is 214·2 F.P.C. (see Table V), we can, by a method of trial and error, arrive at the corresponding value of $\frac{K}{U}$ for the case when the turbine is fed with saturated steam. Thus from Table V, with saturated steam and an hydraulic efficiency of 0·7, U is equal to 194·1, giving $\frac{580 \times 214{\cdot}2}{194{\cdot}1} = 640$ as a first approximation to the appropriate value of $\frac{K}{U}$. The curve in Fig. 4 shows that the hydraulic efficiency corresponding to this is 0·72, whence, by interpolation in Table V, we get 193·4 as a second approximation to U for saturated steam. This gives 643 as the corresponding value of $\frac{K}{U}$, which is near enough to that originally found to require no further adjustment. Of this 193·4 units the amount converted into work is therefore $0{\cdot}72 \times 193{\cdot}4 = 139{\cdot}2$ ft.lb. Centigrade units, whilst with the 214·2 units available with 150 deg. F. superheat, the useful work done is $0{\cdot}7 \times 214{\cdot}2 = 149{\cdot}9$ ft.lb. Centigrade units. Hence the consumption with saturated steam, assuming that the expansion takes place in thermal equilibrium, should be $\frac{149{\cdot}9}{139{\cdot}2} = 1{\cdot}077$ times as much as with steam superheated to 150 deg. F. From Table I, page 53 *ante*, it appears that the consumption with saturated steam is 1·163 times as much. It will be seen from the foregoing that the known

values of the superheat corrections are thus inconsistent with the hypothesis that the expansion of wet steam takes place in conditions of thermal equilibrium.

An obvious suggestion is that the outstanding discrepancy is due to wet steam meeting with a higher frictional resistance. This theory was referred to in the introductory article. As there pointed out this explanation is at variance with Osborne Reynolds's observation* that: "When the motion of a fluid is such that the resistance is as the square of the velocity, the magnitude of this resistance is sensibly quite independent of the character of the fluid in all respects except that of density." In other words, the head lost is then independent of the character of the fluid, whether it be viscous like treacle or comparatively limpid like water. If the velocity be high enough for the resistance encountered by the treacle to be proportional to the square of the velocity, then the head lost will be much the same as with water flowing at the same velocity through the same pipe. This view has received ample experimental confirmation. Professor C. H. Lees, for instance, has shown† that the head lost in a pipe can be accurately represented by two terms, of which the relative importance of the term involving the viscosity of the fluid diminishes as the velocity rises, but in any case varies only with the 0.35 power of this viscosity. Viscosity has therefore, he observes, "only a small influence on the result." It does not appear, therefore, that any material difference is to be expected in the fluid friction of superheated and of wet steam. If any exists it is probably due to secondary causes.

It results from the foregoing that the ordinary theory leads to large and inexplicable anomalies in the superheat corrections as established by experience.

(To be continued.)

THE SALT TRADE OF THE UNITED STATES.

(Concluded from page 79.)

In any open-pan process a considerable quantity of heat escapes with the heated vapour, and the next improvement was to utilise the lost heat units. Owing to an abundance of cheap fuel, little study had been given to the subject of economical evaporation. Cheap fuel has had much to do in localising an industry of which the raw material is so plentifully and widely scattered. In some districts, the salt manufacture has been carried on in connection with some other industry in order to utilise heat that would otherwise go to waste. Cheap and readily-available fuel from the lumber mills of Michigan fostered the salt industry in that State, and some firms will undoubtedly discontinue making salt as lumbering declines. In other places, exhaust steam has been supplied from the neighbouring plants of traction companies or from electric plant. Competing firms, less favourably situated, have had to rely on more economical heating methods, and the vacuum-pan process already in use in manufacturing sugar was introduced into the salt factory about 1885. That it was not utilised sooner, was due to difficulties experienced in crystallising the salt in the pans, but with the removal of this obstacle, the plan of multiple-effect evaporators has advanced rapidly in favour, and is now used in all districts where salt is produced in the largest quantities. The general principle is well understood and only the briefest reference is necessary. The object desired is that the steam produced by boiling brine in a closed vessel should transfer its heat to brine in a second closed vessel, and that this process should be repeated in a series of closed vessels, by maintaining in each such relative pressures as will cause the respective boiling points of the brine contained in each to be lower from the first to the last of the series, so that the steam produced from the brine in each vessel may be condensed in another vessel immersed in the brine of the next succeeding. Inasmuch as the boiling point of liquid varies with the pressure to which it is subjected, the boiling point may be placed at will between certain practical limits. The lowest point is usually fixed by the cost of procuring a vacuum, and is about 125 deg. F. The upper limit is fixed by the temperature of the steam used, which may be, for exhaust steam, about 225 deg. F. Where triple effects are used, the vacuum as measured in inches of mercury is successively maintained at about 15 in., 24 in. and 27 in., the object being to maintain in the last effect as nearly perfect a vacuum as practicable.

Vacuum pans are usually iron or steel vertical cylinders with conical ends. The diameter is generally more than 9 ft., and the tendency is to increase in size. One recently erected had a diameter of 30 ft., and is capable of producing in triple "effect," 1,000 tons of salt per day. The details of construction vary considerably, but the general lines on which they are built can be inferred from Fig. 5, in which are shown the essential parts of a Swenson evaporator. These consist of the evaporating chamber, the steam chest, the cone-shaped bottom,

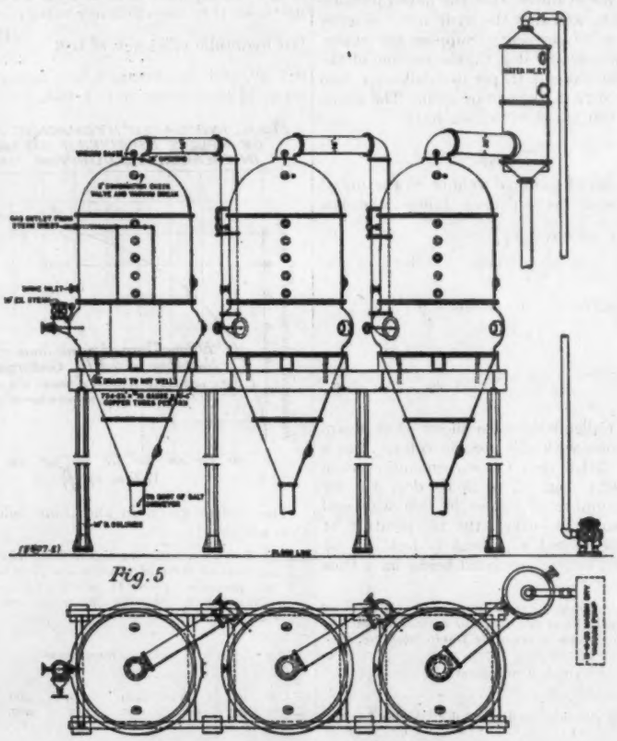


Fig. 5

Fig. 5. The Swenson Triple-Effect Evaporator.

and the barometric leg. "The evaporating chamber is dome-shaped and of sufficient height to prevent loss by entrainment. The steam chest is fitted at the top and bottom with tube plates, into which are expanded a number of 2½-in. copper tubes. The downtake is in the centre of the steam chest, and is of sufficient size to prevent the clogging of the salt crystals as they are formed. The brine circulates up through the copper tubes and down the central downtake. The salt crystals, as formed, drop into the quieter part of the cone-shaped bottom, through the barometric leg into the boot of an enclosed elevator, which drops them into the drying bin."

In the early days, great difficulty was experienced with the gypsum that so coated the tubes that they required boiling and boring out every two hours. Great improvements have been introduced, but the deposition of gypsum is one of the main difficulties against which the salt manufacturer has to contend. This trouble will continue, for the brine of all the important fields carries more or less of this sulphate. In many modern plants, so great is the deposit that the operation of boiling out has to be effected every day, and in order to maintain the apparatus at maximum efficiency, at frequent intervals the pans have to be cooled and the gypsum scale removed from the copper tubes in the steam belt, usually by boiler-tube cleaners operated by compressed air. The principle of superheating the brine at high pressure and of releasing the pressure suddenly, with the view of effecting the precipitation of the gypsum, has been tried, in some plants with good effect, but in general, there seems to be no alternative to stopping the process and scaling the gypsum. Any chemical treatment that would effectually rid the brine of calcium sulphate, lime, magnesia, and oxide of iron is too expensive to be practicable.

Before quitting the subject of evaporation, it would be convenient to consider the relative efficiencies of the different processes employed, but, unfortunately, Mr. Phelan has not been able to collect trustworthy and comparable data. He attempted to base an inquiry on the unit cost of making salt, but the information received was so unreliable that comparison was impracticable. Interested motives may interfere with accurate statistics, but in the uncertain condition in which the industry is at present, and to which allusion has been made, it is to be hoped that exact data relating to the subject will be published. The inquiry, though necessary, is not simple, because of the entry into the problem of many variable factors, such as the concentration and composition of the brine, the nature and calorific value of the fuel, the humidity of the atmosphere, with other evidently disturbing causes. The more trustworthy determinations show that a kettle "block" can produce 2,520 lbs. of salt from 67 deg. brine, for each ton of anthracite dust used as fuel, and 4,088 lbs. from 96 deg. brine from the same fuel. Accepting these figures, the evaporating efficiencies work out, respectively, to 5·83 lbs. and 6 lbs. of water per lb. of fuel. Chatard, whose work long remained a classic in the salt-making industry, concluded that 1 lb. of coal evaporated 5·72 lbs. of water in the direct heat open-pan process, and 6·47 lbs. of water in the high-pressure grainer process. Presumably, the same kind of coal was used in the two conditions, but the statement is vague. A more elaborate analysis has been made by Wilcox (1907) on a Michigan plant, working under normal conditions, in a grainer equipped with submerged mechanical rakers as described, and heated by exhaust steam, that entered at an average temperature of 216·6 deg. F., and had an average quality of 97 per cent. The grainer was of about the usual dimensions, containing 1,072 ft. of 3·5-in. pipe,

* "Scientific Papers," vol. ii. page 237.

† Proceedings of the Royal Society, vol. xli, page 46.

the ratio of the evaporating area to the heating surface being 1·34. The brine at 92·5 per cent. saturation was run into the grainer at a temperature of 71·6 deg. F., and the test was continuous for, 192 hours. The main results of the run are valuable though they cannot be used comparatively.

Results of Operating a Grainer in Michigan for 192 *hours.*

	Lbs.	Lbs. per hour.
Total production of hot salt...	110,950 or	577·8
Total condensation of water from grainer pipes ...	410,368 or	2,137
		Lbs.
Production of hot salt per sq. ft. of grainer surface		72·7
Production of hot salt per sq. ft. of heating surface		97·9
Production of hot salt per linear ft. of 3·5-in. steam pipe		102·5
Production of hot salt per cub. ft. of brine		13·46

Volume of Steam Condensed and Quantity of Hot Salt produced during Successive Periods of approximately Uniform Production.

Duration of Period in Hours.	Total during Period.		Rate per Hour during Period.		Steam required to Produce 1 Lb. of Hot Salt in Lbs.
	Hot Salt Produced in Lbs.	Steam Condensed in Lbs.	Hot Salt Produced in Lbs.	Steam Condensed in Lbs.	
9	*	26·220	—	2·924	—
37	29·297	91·354	684	2·466	3·605
53	32·966	110·570	623	2·086	3·348
17·5	11·783	39·296	673	2·245	3·336
34·5	20·896	69·286	605	2·008	3·01
4	2·468	7·594	617	1·898	3·076
24	10·640	45·452	443	1·477	3·18
13	6·900	24·040	531	1·849	3·49

* Production sufficient only to fill the "clearance" on the bottom of the Grainer.

Wilcox concluded from these figures that the efficiency corresponds to the evaporation of 8·322 through a drier (Fig. 7). The main feature of this apparatus is a rotary cylinder provided with a steam-jacket, or such contrivance, to heat the salt to a high temperature while passing slowly through the machine. An auxiliary steam coil may be placed in front of the cylinder and a blower to force in hot air and at the same time to blow out impurities, such as gypsum. Great precautions are taken to prevent the dust being disseminated throughout the plant. The salt, after passing through the drier should not contain more than 0·1 per cent. of moisture.

The next operation is to pass the dried salt through screens to remove lumps and to assort the grains for the trade. Fig. 8, subjoined, shows the type of screen used. Cylindrical wire mesh screens, shaking screens, or bolters, are used to deflect the grains of various size to appropriate

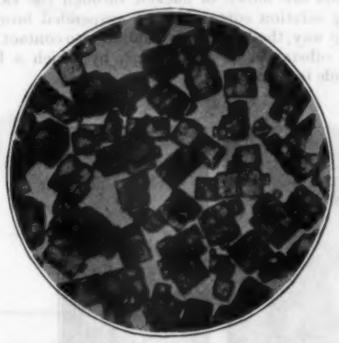


FIG. 6A. SALT CRYSTALS FROM TRIPLE-EFFECT VACUUM PAN. MAGNIFICATION 18 DIAMETERS.

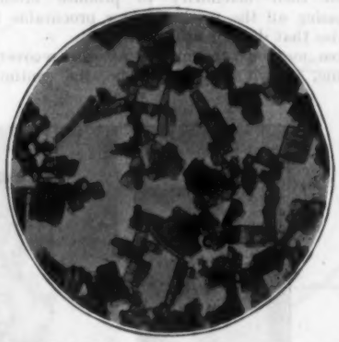


FIG. 6B. SALT MADE BY "GRAINER" PROCESS. MAGNIFICATION 18 DIAMETERS.

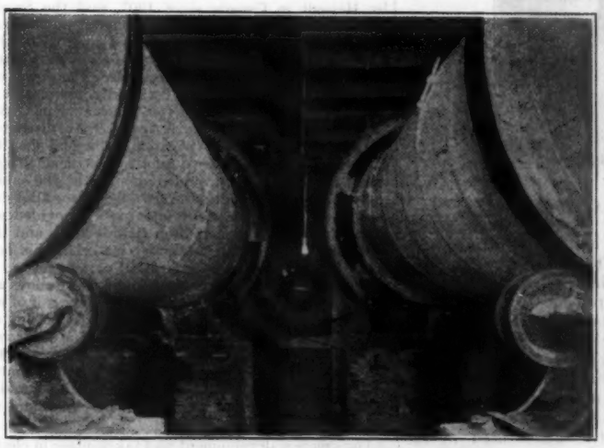


FIG. 7. ROTARY-CYLINDER DRIER FOR HIGH-GRADE SALT.

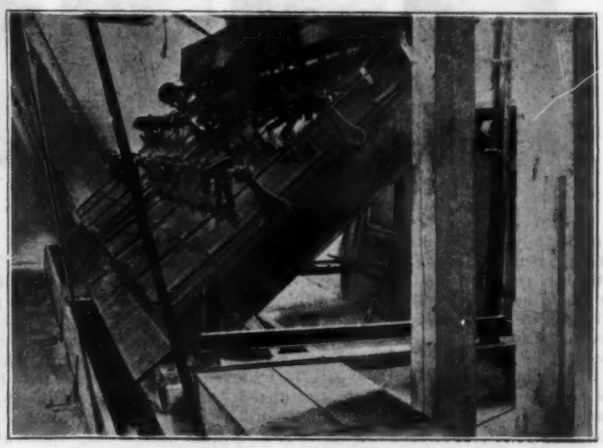


FIG. 8. SCREEN FOR REMOVING SALT.

labour, mechanical skill of an advanced type is courted and encouraged, while the suggestions of the chemical engineer are received with respect.

In addition to the salt that is procured from natural brines, or from the strongly-saturated artificial brines that are formed by allowing superficial waters to dissolve the deep-seated salt and afterwards recovered by pumping and evaporation, a brisk trade is done in some districts by mining rock salt in the solid state. The relative quantity and value of brine to rock salt is shown by the following figures :—

Production and Value of Rock and Brine Salt in the United States in 1915 :—

Material.	No. of Short Tons.	Value in $.
Rock salt	1,165,387	2,299,894
Brine salt	4,187,023	9,447,792

It is thus seen that brine salt contributes about 78 per cent. and rock salt 22 per cent. to the total, and that the cost of a ton of brine salt is greater than a ton of rock salt in the proportion of 2·26 : 1·97 dols.

New York State, Michigan and Kansas are the principal seats of the rock salt trade, and the operations are necessarily fairly similar in each State. In New York, the shaft of 1,000 ft. depth encounters a salt bed 8 ft. thick. The mining is carried out on the pillar and room system. The pillars are 30 ft. square, and the rooms are run about 30 ft. wide, rather more than half the salt being removed. Drilling is carried on with 1¼-in. auger drills, operated by 3¼-h.p. electric motors, at the room face. Great care is taken not to break into the roof, or to pick up the floor. The haulage is generally of a simple character, and the salt is delivered at the mill in lumps of a cubic foot and less. The product is dumped on grizzly or riddle bars made of cast steel, and arranged in tiers. The finer salt falls through the grizzlies into a hopper, and most of the coarser part is crushed between large rolls, though part may be carried by conveyors to be loaded on cars for shipment. Besides these lumps, four market

lbs. of water by 1 lb. of coal—a marked improvement on the older figures just quoted.

We may now follow the salt produced by one of the methods described above through the remaining operations which fit it for use. Partial drying by means of centrifugals removes much of the brine and bittern adhering to the crystals, as they leave the grainer or the vacuum pan. These arrangements are very effective, and further drying and milling operations are generally confined to the preparation of table and dairy salt. The salt crystals have the form shown by the photographs reproduced in Figs. 6A and 6B, annexed. The sample marked A was made in a vacuum pan ; B, by the grainer process. In the latter method the salt assumes a loose, light, flaky texture, but by varying the temperature and the consequent rate of evaporation, the appearance and the granulation can be kept under control. In the vacuum-pan, a finer-grained granular salt results, and it is sometimes necessary for trade purposes to produce a salt possessing both characteristics. When the removal of moisture has to be carried further than is possible in the centrifuges and in storage bins, the salt is passed hoppers and bins. The salt may now be considered ready for use, though when a salt for table use is required that should be moisture-proof, a small amount of some chemical of a non-hygroscopic character, usually magnesium carbonate, is used to coat the grains. This account of the brine salt industry began with a quotation from Chatard ; it may be closed by a reference to the same authority. In 1888, he noticed that the machinery employed was of the simplest character, and afforded little opportunity for the introduction of labour-saving devices ; that the labour engaged was comparatively unskilled, and that handling, transportation and distribution of the product were effected in the cheapest manner. To-day success, commercial success, depends in a great measure upon taking advantage of labour-saving devices. The salt is moved by hand as little as possible, self-acting machinery is adopted wherever possible, and in some of the grainer and vacuum plants, the salt is not touched by hand from the time it crystallises from the brine, till it is weighed and packed into the cartons ready for the trade. The machinery grows increasingly complex, and in place of unskilled

sizes are recognised in the trade. These are illustrated in Fig. 9, subjoined.

It remains to inquire into the prospects of a profitable industry in bromides and calcium chlorate. The recovery of the former from natural brines is a systematised operation in some plants where the grainer process is used, but in ordinary times the treatment of the bittern for bye products can hardly be regarded as commercially successful, as it has to encounter severe competition from other sources of production independent of salt manufacture. Before the war, the manufacturers had to store their product, being unable to find a market, but owing to the interruption of import from Germany, a drain on the home output has followed, and prices have become remunerative. So profitable for a while was the bromine industry, that some Michigan firms discontinued to make salt, and utilised their machinery to produce bromides, purchasing all the mother liquor procurable from factories that did not utilise it.

Three methods are in use for the recovery of bromine, known as the periodic, the continuous, being only 60 per cent. Attempts, therefore, have been made of late to improve and to cheapen the process. Earthenware coils have been substituted for leaden pipes, and simpler methods have been devised for liberating bromine from bromide and bromate solutions. The continuous method is free from some of the disadvantages inherent in the older process, but involves the necessity of preparing chlorine, either by electrolysis, or by chemical processes for in this method, chlorine gas is the agent used to liberate the bromine. The brine is drawn off into shallow tanks, and on passing the chlorine through the waste, the bromine is set free according to the simple formula—

$$M\,Br_2 + Cl_2 = M\,Cl_2 + Br_2$$

(M standing for any metal.)

leaving the bromine mechanically held in solution. The liquid is allowed to drip from the tanks, and air currents are blown or sucked through the slowly-falling solution containing the suspended bromine. In this way, the bromine is brought into contact with some substance, as iron filings, by which a ferric bromide is formed.

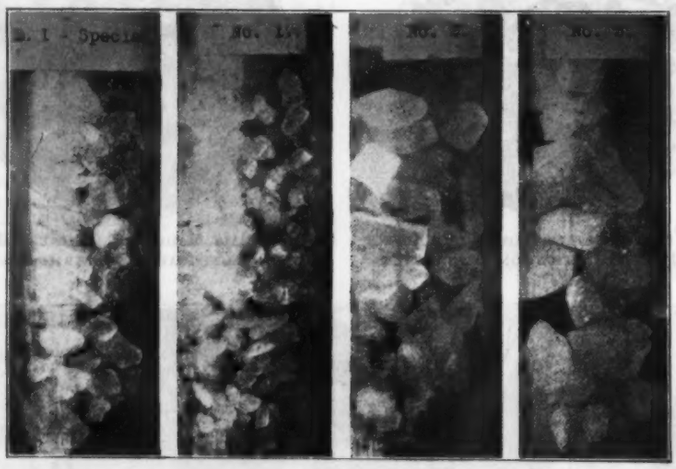


Fig. 9. Examples of Coarse-Grain Rock Salt from Kansas.

and the electrolytic. The first has been longest in use, and the general practice is to concentrate the strength of the refuse bittern by further evaporation, till the liquid has a strength of about 40 deg. B., when it is transferred to a bromine still, that is made of some material, usually a selected sandstone, capable of resisting both bromine and acid action. These stills are required to hold 400 gals. to 1,200 gals. of liquid, and have to be carefully constructed. The concentrated bittern being placed in the still, and sodium chlorate and sulphuric acid added, a jet of steam is discharged into the solution to raise the temperature, and a reaction takes place which is approximately represented by the equation

$$3\,Mg\,Br_2 + 3\,H_2\,SO_4 + Na\,ClO_3 = 6\,Br + Na\,Cl + 3\,Mg\,SO_4 + 3\,H_2\,O.$$

The reaction, however, is more complex than the equation indicates, for some chlorine passes with the bromine gas. This impurity is removed by milk of lime, which forms with the chlorine, calcium chloride and calcium hypochlorite. The distilled bromine next passes through a condenser of leaden pipes, extending from the still to three glass collecting bottles in series, sealed to one another and to the worm. Any bromine that passes the last bottle will be very dilute, and is caught in towers, 7 ft. high, and 2 ft. in diameter, made of sewer pipe, and filled with coke. Any bromine that collects in them runs out at their base. About 1 lb. of bromine is obtained from 20 gals. of bittern, having a strength of 40 deg. B.

The periodic process is expensive. The apparatus is costly, the lead condenser requires to be constantly renewed, the volume and weight of the liquid handled is disproportionate to the amount of product, considerable heat is required for distillation, and the efficiency is low, the recovery of the bromine present in the original brine from the mother liquor

The electrolytic process has hardly arrived at a practical stage, for Mr. Phalen has not seen the method in operation in the United States. The method depends on the principle that bromides decompose at a lower voltage than chlorides, and hence are first reduced on the passage of an electric current. The maximum efficiency is given by a weak current of not more than four or five volts, but in any case some chlorine will always be produced, which, however, can be eliminated subsequently. This method is, apparently, much used in the treatment of the Stassfurt residus, and it is said that the resulting product has been largely employed in preparing the asphyxiating mixtures that have proved so deadly in the present war.

After the bromine has been removed, the bittern generally goes to the calcium chloride plant. Where the bromine is not recovered, the bittern is usually concentrated to the strength of 45 deg. B., the volume then being about 8·5 that of the original brine, one-third of which is calcium chloride. This liquid goes to the storage tanks, and the suspended matter thrown down by milk of lime, leaving a clear supernatant liquid, which is run into kettles for final evaporation. The liquor is boiled till it has the consistency of a thick syrup. A plug is then drawn from the bottom of the kettle, and the thick liquid is run into metallic drums, in which it solidifies on cooling. It is then ready for market.

The Finspong Works, Sweden.—The well-known Finspong works, Sweden, are increasing their capital from 6,800,000 kr. to 10,400,000 kr. Half of the new shares are free shares to the shareholders, paid for out of the company's earnings, the other half being issued in the ordinary manner. One of the reasons for the increase of capital is the planned erection of new plate works.

METALLURGICAL ELECTRIC FURNACES.

(*Concluded from page 87.*)

Industrial Electric Furnace Methods.

Though Mr. H. Etchells, B.Met., of Messrs. T. H. Watson and Co., Sheffield, had given his paper the general title, "Application of Electric-Furnace Methods to Industrial Processes," he excluded the production of aluminium, soda, zinc, tin and lead from his review, because the operations were not, he said, carried out at temperatures to produce furnace problems. One of the most successful pioneers in resistance furnaces, T. F. Baily, of Cleveland, Ohio, had now a number of his furnaces, up to 900 kw., in use for annealing steel, German silver, and other metals. His resistor material, of broken electrode carbon, granulated coke, &c., was, he said, disposed in an open trough encircling the hearth, and received current through graphite electrodes which penetrated through the furnace walls; the difficulty was that the material of the trough tended to fuse and run, particularly owing to ash accumulation; even carborundum, which gave the best protection, became a conductor at high temperature. Yet the furnaces had recently been applied with success to the melting of brass, gunmetal, and low-melting non-ferrous alloys; the power consumption was stated to be 400 kw. hours per ton. of yellow brass on a 24-hours' day. Resistors for temperatures above 1,100 deg. C., he continued, were being studied. From the central station view point, the resistance furnace had the advantage of being exactly controllable and not subject to the numerous shut-downs of the arc furnace; the load factor could be kept up to 80 per cent., and the maximum demand should not exceed full load by more than 10 per cent. Graphite and carborundum had, for many years, almost exclusively been American products of such furnaces, but Great Britain, Norway and France now entered into competition; it was interesting that one carborundum furnace of this country was of the arc type.

Almost all smelting furnaces verged on the border between resistance and arc-furnaces. Smelting furnaces for copper oxide ores and residues had a big development in America, electric iron smelting had been tackled by Héroult in Canada since 1907, and the Swedish "Elektrometall" furnace seemed to be an industrial success. These latter furnaces absorbed up to 7,000 h.p., the charge acted as resistor; the regulation was obtained by raising and lowering the electrodes; the power consumption was stated to be 2,235 kw. hours, and the charcoal consumption 0·40 ton per ton of pig. Such smelting furnaces were fairly localised to districts in which electric power was cheap and charcoal plentiful; but there was a large scope for the electric smelting of iron sands and finely-divided ores with the aid of carbon in other forms than charcoal. Ferro-alloys and calcium carbide were made in furnaces provided with rammed carbon bottoms, often water-cooled, and their walls were built up of refractory material, this being either the actual raw material itself or magnesite; the charge was tapped or allowed to solidify. The alloys were refined in furnaces of the steel-melting type; if of high melting-point, they had to be chipped out. Alloy and carbide furnaces absorbed much energy, a 5 per cent. ferrochrome, *e.g.*, required 7,000 kw. hours per ton. This industry had, therefore, developed in countries where hydro-electric power was available, and it might be attracted to parts of Wales, Scotland and Ireland.

The greatest development had taken place in electric steel making. Intricate steel castings, gear wheels, &c., from the electric furnace, needed only touching up with the file, the steel, of 30 tons tensile strength, 30 per cent. elongation, and 40 per cent. reduction of area, would bend double as cast, and required only reheating, not annealing. The relative merits of basic and acid steel for castings were still controversial. It was claimed that the electric furnace had fulfilled its function by clearing up the accumulations of steel turnings alone, and that refining for sulphur and phosphorus was superfluous; but in Mr. Etchell's opinion, only the best quality would command a profitable price after the war. Signal success had been attained particularly in complex high-speed tool steels; Mr. Etchells showed a photograph of a 14 per cent. tungsten steel made in his furnace, drawing attention to the uniform fracture; it was a piece knocked off a half-ton ingot from a 3-ton casting. Several Sheffield firms now dispensed with the crucible process, being convinced of the uniformity of the electric-furnace products. The United States were now working over 200 electro-furnaces, and the production of electric steel in Germany was said to have risen from 90,000 tons in 1914, to 225,000 tons in 1916.

These alloys, the speaker said, were made in furnaces of the contact arc type, the three favoured types being the Héroult, Elektrometall and the Greaves-Etchells, though there were other types with higher power factors and steadier regulation. Fig. 9, page 111, illustrated the general arrangement of the current

supply on the three-phase system, to a 12 ton-Greaves-Etchells furnace. The primary windings of the transformer were connected in delta, as shown on the extreme right of the diagram; the secondary windings were coupled in star. Each of two of the secondary windings was joined to one of the two furnace electrodes; the third secondary winding sent one branch to the hearth, and the other to earth. As it was impracticable to make the hearth resistance equal to the resistance of an electrode arc, the system was unbalanced; by a system of special transformation

Primary windings of different phase relationship, the secondary current was not in phase with either, and being out of phase, the power factor of that particular secondary circuit was materially lowered, so that any excess of current due to a short circuit on the electrode was again checked by the increasing reduction of the power factor. Provided the currents were normal, the lagging power factor of the one side of the system was balanced by the leading factor of the other; thus the overall power factor was good, being lowered only at the moment of a short circuit; this was the

an electrode short-circuiting, or suddenly dropping and breaking, the arc. But things were improving. He had just started a furnace on a 6,600 volt system; one switch, set at 100 per cent. overload, had come out once only during the complete heat, while the other, in series with it, set at 50 per cent. overload,

Fig. 9.

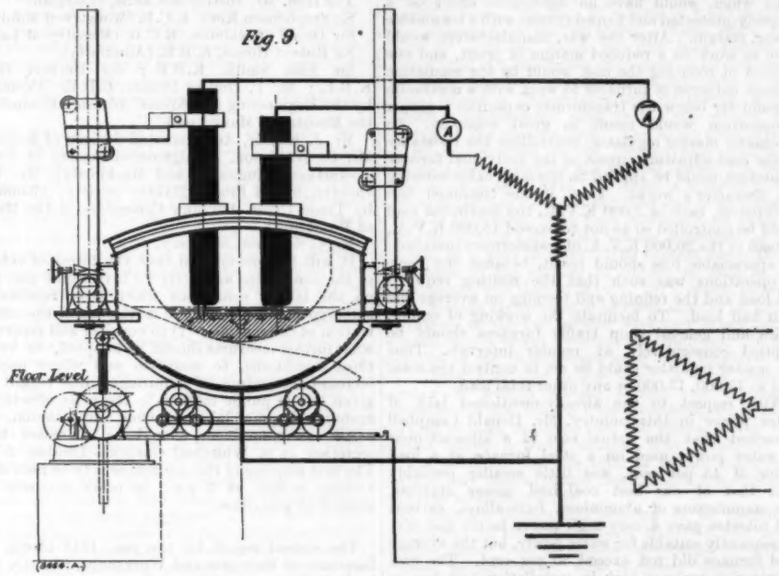
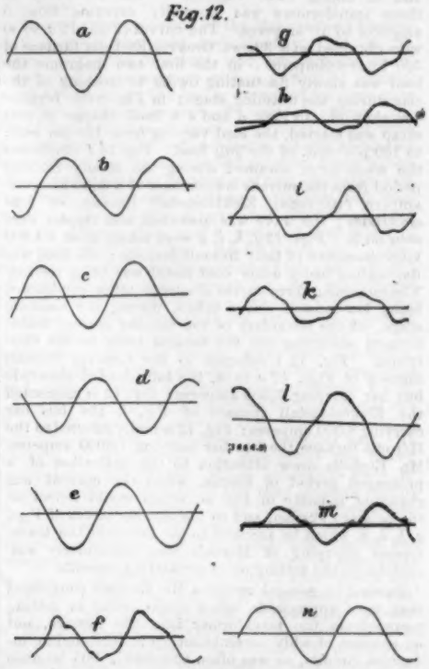


Fig. 12.



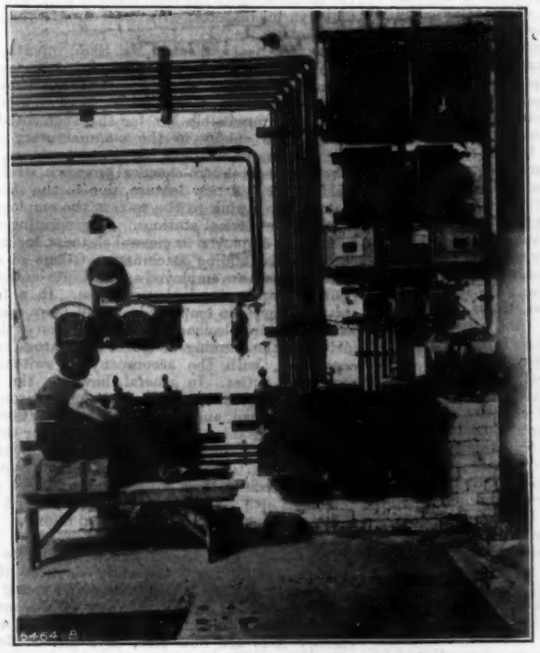


FIG. 10.

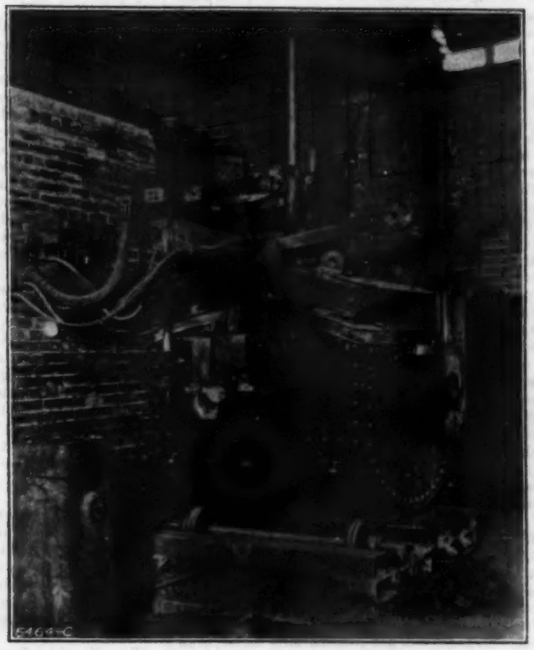


FIG. 11.

ratio and by special construction of the hearth branch winding he and his collaborators were, however, able to give a balanced load on the high-tension supply phases. The currents fed into the furnace through the electrode-arcs had to return by passing through the hearth, this being the path of least resistance; at working heat the hearth resistance was uniform, and it acted as a limiting check when the current increased unduly owing to the formation of a short circuit if the electrodes touched the fluid metal. Any current crossing from one electrode to the other, or through the furnace hearth, had to pass through two secondary windings in series; since each of these was excited by

advantage of the Greaves-Etchells system over others, in which the overall power factor was low. Another advantage was that heat was generated in the furnace linings so that the steel was not chilled at the bottom, and a good circulation upward was maintained. Like Elektrometall they worked with two independent arcs, and the regulation could therefore be entrusted to a boy (see Fig. 10). Mr. Etchells did not give further particulars of the furnace illustrated in Fig. 11.

Electric furnaces, Mr. Etchells continued, still offered a number of interesting problems to the electrician. Regulation was uneven, and automatic regulation could not prevent lumps of steel scrap falling against

had come out several times. Unreasonable importance had been attached in the past to the power factor; furnaces were now available which gave 85 per cent. to 90 per cent. power factor during melting, and up to 93 per cent. during refining, but it should be borne in mind that increased resistance, and consequently a lower power factor, was often more necessary for creating the best conditions for the supply network.

Regulation, phase-balance and wave-distortion had not received the attention they deserved. Mr. Etchells exhibited in this connection some interesting Duddell oscillograph curves, taken with the aid of Mr. S. Z. de Ferranti's staff on different types of furnaces in

Sheffield, where supply was on 11,200 volts three-phase at 50 cycles. We reproduce some of these curves in diagrams Figs. 12 *a* to *n*. Nearly all furnace installations were fitted with current transformers on the incoming high-tension phases (for operating the protective gear), and in taking these volt curves the secondary of these transformers was normally carrying from 5 amperes to 10 amperes. The curves (Figs. 12 *a* to *e*) were obtained on a 30 cwt. Greaves-Etchells furnace of 520 kilovoltamperes; in the first two diagrams the load was slowly fluctuating owing to frothing of the slag during the finishing stage; in Fig. *c* the furnace was shut off; in Figs. *d* and *e* a fresh charge of cold scrap was started, the load varying from 120 per cent. to 150 per cent. of the full load. Fig. 12 *f* illustrates the wave form obtained during the steady refining period from the current transformer of a 3000 kilovolt-ampere (10 tons) Elektrometall furnace of four electrodes; the wave was distorted, and ripples were seen on it. Figs. 12 *g*, *h*, *i*, *k* were taken from a 1,800 kilovoltampere (6 ton) Héroult furnace; the load was fluctuating badly while cold metal was being melted. The remaining three curves illustrate other conditions, being low-tension waves taken, during the finishing stage, off the secondary of the bus-bar current transformers encircling the low-tension leads to the electrodes. Fig. 12 *l* referred to the Greaves-Etchells furnace of Figs. 12 *a* to *n*, the fully-loaded electrode bus bar carrying 3,500 amperes; Fig. 12 *m* concerned the Elektrometall furnace of Fig. *f*, the bus bar carrying 8,000 amperes; Fig. 12 *n* finally referred to the Héroult furnace the bus bar carrying 1,8000 amperes. Mr. Etchells drew attention to the indication of a prolonged period of inertia, while the current was changing polarity in Fig. *m*, which would reflect on the primary system, and to the curious waves of Figs. *g*, *h*, *i*, *k*, which he ascribed to the fact that the transformer grouping of Héroult was particularly susceptible to the setting up of circulating currents.

Passing to general remarks Mr. Etchells considered that very appreciable losses might occur in getting power from the transformer into the furnace, not on account of eddy currents set up in surrounding inductive circuits, as was often suggested, but because of the skin resistance in the furnace leads; with currents of 10,000 amperes at 70 volts or 80 volts these losses might assume serious proportions. The electrode losses also called for earnest attention. The continuous-feeding carbon electrodes (pitch, coke, anthracite, &c.) were provided with jointing nipples, which for amorphous carbon should always be made of graphite. For steel making graphite electrodes were, however, infinitely superior to amorphous carbon electrodes, because they could carry 100 amperes per sq. in., instead of 25 amperes per sq. in., and because they were lower in consumption and more convenient in handling. Sealing glands for the electrodes on the roof and sides were another important feature, and their own flexible air-cooled electrode holders were preferable to rigid water-cooled holders. The refractory materials remained the chief difficulty, however.

In his contribution to the discussion, Mr. Donald F. Campbell, of Westminster, commented upon several important points, dealing first with the fallacy that cheap water power was essential for electro-metallurgy. The electro-steel furnaces of England were now producing 40 times the pre-war output; it was possible to do without the large imports of Swedish iron, and the approaching exhaustion of high-grade Cumberland ores might be looked upon with equanimity, because the inferior ores of Cleveland and the Midlands could, in the electric furnace, be worked into a steel of great purity. That might give new life to the basic Bessemer process of Thomas and Gilchrist throughout the minette region of Lorraine, and the phosphoric ores of this country might further be utilised as fertilisers. But the currents of 10,000 amperes and even 20,000 amperes of the electric furnace involved complex problems. The actual efficiency of steel furnaces was probably within 5 per cent. or 10 per cent. of the maximum obtainable without some radical change in the application of heat, and the efficiency of large-size furnaces was not substantially higher than that of small types. The maximum size would hardly rise much about 30 tons, and that size was only likely to be appied for refining liquid metal or for especially large ingots; some furnaces of that capacity were in use in the United States and in Germany. For the melting of old scrap a 1,500 K.V.A. furnace was as efficient as any, and 17 out of 53 furnaces of a well-known make erected in this country in 1917, and 60 out of 116 in an allied country, were of this capacity. The furnace size would mostly depend upon metallurgical considerations and the product required, and these questions should have precedence over electrical considerations or supposed economies.

In deciding upon the suitable type of furnace the first points for consideration should be the nature, acid or basic, of the refractory lining, and whether there would be fast melting of small charges at frequent intervals, or a large charge every few hours. The small acid-lined furnace for castings and high-grade tool steel had not sufficiently been adopted, and the use of large basic furnaces for refining liquid basic steel had been neglected over here, whilst abroad 25 ton to 30 ton furnaces were in regular operation. As regards power supply and costs, consumer and supplier were not in sufficiently close co-operation. The consumer was often inconsiderate as to maintaining a high load factor at a moderately even load. The supplier was frequently unreasonable about small load fluctuations which would have no deleterious effect on a properly-protected and looped system with a reasonable power margin. After the war, manufacturers would have to work on a reduced margin of profit, and one method of reducing the cost would be the regulation of large batteries of furnaces to work with a maximum demand far below the transformer capacities; proper co-operation would result in great economy. An automatic master regulator, controlling the resistance in the load-adjusting circuit of the individual furnace regulators, could be applied on the main cable entering the consumer's works. Thus, if one consumer had 10 furnaces, each of 2,000 K.V.A., the maximum load could be controlled so as not to exceed 15,000 K.V.A., instead of the 20,000 K.V.A. of transformers installed; no appreciable loss should result, because the cycle of operations was such that the melting required full load and the refining and teeming on average less than half load. To facilitate the working of cranes, ladles and general shop traffic furnaces should be emptied consecutively at regular intervals. Thus the master regulator could be set to control the total load at 12,000, 15,000 or any other total load.

With respect to the already-mentioned lack of water power in this country, Mr. Donald Campbell remarked that the actual cost of a kilowatt-hour of water power used on a steel furnace at a load factor of 45 per cent. was little smaller probably than that of our best coal-fired power stations. The manufacture of aluminium, ferro-alloys, carbide and nitrates gave a very high power factor and was consequently suitable for water power, but the average steel furnace did not exceed 40 per cent. The cost of water power was high in installation and low in running, steam power was low in first cost and high in running cost. The difficulties of transport and of obtaining skilled labour in the remote districts of available water power would ensure the stability of the electric steel industry in this country, and all power companies should prepare to supply power in bulk to meet the common need. Consumers, on the other hand, should consider regulation of their demands, not as regards petty fluctuations, which the power companies would soon neglect, but as regards maximum demand over periods of 30 minutes or 40 minutes. The future development of the industry depended largely upon a broader point of view on the part of the power companies and a wider appreciation on the part of our chemists and metallurgists of the vast possibilities of intense heat in the neutral atmosphere of an electric furnace. Several new, essential industries had already been established on a substantial basis in this country during the last three years, with results surpassing expectations.

The question of utilising electric furnaces after the war was, however, causing anxiety to some manufacturers, as the large supplies of turnings from shell factories would no longer be available. But many electric furnaces could no doubt compete successfully with basic Siemens' furnaces for miscellaneous scrap collected throughout the country which could be refined to replace imported Swedish steel. The principal competitors of those scrap-melting furnaces in the Midlands would be the furnaces refining liquid steel on the north-east coast. In any case, Scandinavian imports would practically cease, the high-class steel industry would be self-supporting, the ferro-alloy works already firmly established would smelt tungsten and chrome ores from the country and the dominions, and the British Empire should be able to provide all qualities of steel essential for the industries of peace and war.

We will only refer to one other point mentioned by Mr. Thomas Annis during the discussion. It concerned the refractory-material difficulty. In carbide furnaces the cold or resolidified charge forms a protection for the furnace wall. In a similar way Mr. A. C. Higgins is said to use chilled alundum as a lining for the molten alundum in contact with the hot metal, a perforated water pipe on the top of the alundum shell keeping the outer layer of alundum cool.

Trading with the Enemy Act.—The Controller of the Foreign Trade Department has issued a new list (No. 60) of additions to the Statutory List of firms of enemy nationality or enemy association with whom persons in the United Kingdom are forbidden to trade. Copies of this list can be obtained at a trifling cost from the Superintendent of Publications, H.M. Stationery Office, Imperial House, Kingsway, W.C.

INDUSTRIAL NOTES.

The labour disputes in munitions works, of which we gave a history on page 84 *ante*, are in process of being settled. Work was generally resumed at the various centres in the commencement of the present week, pending the findings of the Committee of Inquiry appointed by the Ministry of Munitions. We deal with the situation in a special article on page 120 of our present issue.

The Committee of Inquiry consists of the following:—
The Hon. Mr. Justice McCardie, chairman.
Sir Stephenson Kent, K.C.B. (Ministry of Munitions).
Sir David Shackleton, K.C.B. (Ministry of Labour).
Sir Robert Horne, K.B.E. (Admiralty).
Sir Alan Smith, K.B.E.; Sir Herbert Rowell, K.B.E.; Mr. F. Dudley Docker, C.B.E. (Nominated by the Engineering Employers' Advisory Committee of the Ministry of Munitions.)
Mr. J. Kaylor, Amalgamated Society of Engineers; Mr. G. Wilkinson, Amalgamated Society of General Toolmakers, Engineers and Machinists; Mr. W. F. Dawtry, Steam Engine Makers' Society. (Nominated by Trade Union Advisory Committee of the Ministry of Munitions.)
Mr. C. S. Hurst, secretary.

It will be remembered that the terms of reference of the committee are:—(1) To investigate and report on the labour conditions which have rendered the embargo necessary, and to advise upon the administration of the scheme; (2) to consider and report as to what further measures should be adopted, in view of those conditions, to maintain and where necessary increase the output of munitions; due regard being given to the public interest in the most effective and economical use of labour, money and material.

All communications should be addressed to the secretary at 6, Whitehall Gardens, London, S.W. 1. The first meeting of the committee is to be held at that address to-day, at 3 p.m., in order to settle their method of procedure.

The annual report for the year 1917 of the Chief Inspector of Factories and Workshops, recently issued by H.M. Stationery Office at the price of 3*d*. net, shows the progress which has been made in workshop practice under various aspects. We gather from it the following brief notes.

The electrical inspector, Mr. Ram, reports that the use of electrical energy has enormously increased during the war, and it may be safely stated that the marvellous output attained by munitions works of all kinds would have been impossible but for the augmented supply of electrical energy in the manufacturing districts. The increase is not only for power purposes, but for other uses as in electro-chemical processes, steel making, welding, &c. A new feature, due to the shortage of male labour owing to the war, is the employment of women in electrical stations. In generating stations, women are employed as general cleaners, including the cleaning of standing machinery. Others of a better educated class are employed as assistants on the switchboards, working under supervision. In a few substations, they are employed on still more responsible work, being in sole charge of the operation of the plant, including the running of motor generators or rotary converters, with the accompanying switching and regulating duties. In general, however, the work of substation attendants is, for obvious reasons, more suitable for men, and schemes are in operation for the training of disabled sailors and soldiers for this work. A number are, in fact, already so employed. This work appears to offer very suitable employment for such men where their form of disablement permits, and opens up a useful field for their permanent occupation, but of course for a very limited number.

The tendency to reduce hours, which has been a growing feature since the early days of the war, continues, and cases where women and young persons are employed for hours in excess of the maximum weekly limits allowed by the ordinary provisions of the Factory Acts are now rare, says Mr. G. Bellhouse, H.M. Deputy-Chief Inspector. From visits paid to a number of works selected so as to give a fair sample of the munitions work in a Division, in which the total number of women and girls employed was approximately 27,000, it was found that in only five cases did the hours actually worked exceed 60 per week; in 32 cases they amounted to 60; in 62 cases they were between 55 and 60; in 51, between 50 and 55; in 20, between 45 and 50; and in 7 they were less than 45. Perhaps one of the most interesting features in this connection is the gradually increasing number of cases in which work before breakfast is being abandoned. Scotland may probably be regarded as the pioneer in this direction, for as long as seven years ago the great Paisley cotton thread firms adopted the 8 a.m. start. The results of the measure are that bad time-keeping in the morning has almost disappeared; sickness among

the girls in the first hours of the morning has largely ceased; reduction in output is hardly noticeable; and better work is secured and maintained.

There has been no general development of the system of eight-hour shifts. Difficulties in regard to this system, more especially those arising from scarcity of labour, still exist, and though they have been overcome in individual cases they have proved generally a complete stumbling block to any wide adoption.

If a broad aspect of the situation in regard to overtime be taken, there is no evidence of undue or excessive fatigue amongst women or young persons. Considering the strain under which work has been carried on and the conditions, in some localities at all events, under which workers have been living, the scarcity of complaints from trade unions or individuals and the absence of signs of breakdown are most remarkable.

In the annual report to which we refer, Miss Anderson, H.M. Principal Lady Inspector of Factories, says that expressions of surprise at the way women have risen to their new opportunities, so often heard by inspectors in 1915 and 1916, have yielded place widely in 1917 to quiet commendation of the way they have held to their work, labouring and unskilled as well as semi-skilled, and there is undoubtedly a growing sense of power and craft pride in the women as they acquire understanding and facility in the more skilled processes. In some cases of employment in highly skilled work requiring considerable training, women are found who have previously been engaged in teaching, technical or literary A skilled woman engaged in examining and measuring the bore of guns was found to have been formerly a lace teacher in Ireland; she was greatly interested in her present occupation and said it was "lovely work." One Scottish cement works is run almost entirely by women's labour which has been very successful with the aid of mechanical appliances, the only men remaining being foremen, engineers and rotary kiln men. In Birmingham, women are increasingly employed in the tool room, and tool-setting, processes hitherto regarded as skilled men's work. In glasswork, in scientific instrument making, women are being trained in lens and prism work and are frequently found in testing, smoothing and polishing processes, semi-skilled or skilled in which training may extend from a few months to several years. At a large steel works in South Yorkshire where the managers were of opinion in 1916 that women would be useless to them, there are now over 300 employed to their satisfaction in light labouring and yard work, painting, labelling and crane-driving. In a Yorkshire factory the women have done so well as regards output in forging or nosing 4·5 shells that they have been put on to 60-pounder shell whose weight in the rough is 100 lb. At a blast furnace in course of erection the foreman in charge who had trained the women spoke exceedingly highly of them and said he would be willing to undertake any ferro-concrete work with women only. They have entirely made over 1,000 piles 31 ft. in length and will be making more. They are bending and preparing all the steel work, work the stone-crushing machines and the concrete mixer, stack the piles when made and discharge stone, iron, &c., from railway trucks. They all look splendidly well and said they never felt better in their lives.

According to Mr. W. S. Smith, H.M. Inspector for Dangerous Trades, the manufacture of dope containing tetrachlorethane finally ceased in September, 1916. During the period such dopes were in use, 70 cases of toxic jaundice, including 12 deaths, came to the knowledge of the Factory Department, in addition to numerous cases of suspension and transference to other work for illness due to the same cause. After the introduction of the so-called "non-poisonous," or tetrachlorethane-free dopes, it became necessary to ascertain the effect of these upon the workers in dope rooms, and information was collected from a number of the medical officers who were periodically examining this class of workers. These reports confirmed the view of the Medical Inspectors of Factories that efficient exhaust ventilation must be maintained at the same high standard, even for the tetrachlorethane-free dopes. No change has been made in controlled factories as to the system of ventilation first recommended by the department for dope rooms. This may be briefly described as a low-velocity scavenge of the air contents of the dope room. In 1917, only 11 cases in which symptoms were attributed to dope were notified to the department from five works by the Factory Certifying Surgeons. All these occurred in factories where the ventilation was not up to the required standard. During this period, however, the number of firms engaged upon doping work has increased over 300 per cent., whilst many of the dope rooms have been doubled and trebled in size; the workers in dope processes to-day may be counted by thousands instead of hundreds in 1916.

The annual report of the Chief Inspector of Factories and Workshops closes with a chapter on Trinitrotoluene Poisoning, by Dr. T. M. Legge, H.M. Medical Inspector of Factories, pointing out the satisfactory progress which has been made in all operations connected with this explosive.

A net gain of 1,481 in the number of women employed on the various divisions of the Pennsylvania Railroad, Eastern Lines, was made during the month of June. This is shown by the daily reports of the division superintendents. On May 31 a total of 6,873 women were employed in the divisional offices, while the report for June 30, which has just been compiled, shows a total of 8,354 female employees on all divisions. This total does not include the departments in the general offices at Philadelphia and Pittsburgh, where altogether considerably more than 1,000 women are working at the present time. The latest compilation for all departments of the Pennsylvania Railroad, Eastern Lines, including the general offices, has been made as of June 1, 1918. It shows a total of 8,767 women in the service on all divisions and in all departments at that time. One year previously, on June 1, 1917, there were only 1,945 women employed, or an increase in a year of 6,822. The earliest compilation ever made of the number of women at work in all departments was that of May 1, 1917, which showed 1,494, making an increase in thirteen months of 7,273.

Previous to the war, women were very rarely taken into the service of the Pennsylvania Railroad. In the majority of the departments none were employed at all. There were, for many years, a very limited number of women station agents and telegraph operators. A few women were also employed in such work as cleaning stations, cars and offices, and in the general offices a small number were employed in clerical positions, but the total of female employees never at any time exceeded more than a few hundred until war conditions arose.

At present, women are working in 69 classified occupations on the Pennsylvania Railroad, and have invaded many lines of employment—some involving manual labour—which were formerly regarded as capable of being filled only by men. To-day 6 women are working, in various of the shops, on car repairs; 1 is employed as a "caller," her duties being to summon trainmen for their run ; 74 women are at work cleaning locomotives; 1 is a crane operator; 4 are employed as locomotive despatchers; 29 are draughtswomen; 7 are draughting apprentices; 5 women are operating steam hammers; 3 are gang leaders; 1 is a coal inspector; 595 are working as labourers; 37 are employed as machine hands; 234 are messengers and assistant messengers; 6 are mechanics' helpers; 2 are oilers; 29 are classed as shop hands; 15 are employed as power operators; 8 are leverwomen; 9 are drawbridge attendants; 2 are switch attendants; 38 work as freight truckers; 1 is a trackwoman; 2 are turntable operators; 8 are upholsterers; 2 are warehouse women; and 92 are employed as crossing-watchwomen. In addition there are 132 signal-women and assistants; 16 bureau of information attendants; 24 parcel-room attendants; 258 store-room attendants; 611 car cleaners; 2 Pullman space distributors; 12 elevator operators; and 81 ticket sellers. In the lines of work more customarily followed by women, there are 105 "janitresses"; 679 telephone operators; 266 telegraph operators; 121 telegraph operator students; 15 cooks and 4,723 girls and women who are classified as clerks, stenographers and typists.

We read in the Paris journal, *L'Industrie Electrique*, that in metallurgical works in France there are now employed over 900 women where about 100 were employed before the war, equal to an increase of about 800 per cent. In transport operations the increase is 450 per cent., in chemical industries it is 164 per cent., and in wood working 154 per cent. A large variety of mechanical appliances have been provided so as to guard the women against all strenuous exertions.

At the half-yearly meeting of the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England, held at Newcastle last Monday, Mr. J. Reay, Stockton, presiding, the financial statement showed a substantial balance in hand. Seven cases of dispute had been settled. The report also recorded advances in wages and bonuses amounting to 25 per cent. for time workers. The chairman, moving the adoption of the report, said that advances granted since the war commenced brought the total to 82½ per cent. As to the next half-year, he believed there would be plenty of work for all, and the difficulty would be to find men to do it. The large majority of their men were working well and regularly. Mr. T. B. Pugh, vice-president, seconding the motion, said that their Board had demonstrated the possibility of settling disputes by conciliation and arbitration, and they trusted that the time was not far distant, not only in industrial concerns but in every other when similar means would be adopted.

The half-yearly meeting of the Manchester Chamber of Commerce was held last Monday. Mr. R. B. Stoker, M.P., the president, who occupied the chair, stated that in connection with a system of registry which the Chamber had had in operation for some time past for the employment of disabled officers, the Board had been asked recently to extend their work in support of a more comprehensive scheme embracing both officers and men. He had received many letters from members of the Chamber in strong sympathy with the effort, but in some instances attention had been called to the gravely deteriorated character of the services of these men, and it was said that many of them seemed to be rather "out for a soft job." They must bring to bear on those cases a very great amount of sympathy and tact. A man who had experienced the horrors of modern warfare was from time to time haunted by the memory of his experiences, and in those phases the pent-up emotions excited by his memories overwhelmed him and made work impossible. He appealed to employers and employees to recognise that state of affairs and make due allowance for it.

Coming Government restrictions on the general use of coal and coal-gas had cast their shadows over the industries in which coal played an essential part. In addition to the shortage of man-power the heavy requirements of France, whose coalfields were in German hands, and of Italy had been decisive factors in increasing the stringency of the whole situation. Whatever might be the cause, however, it had been stated on the highest authority that absenteeism was indulged in to an alarming extent, being in some cases as much as 40 per cent. of the men's time, and it was estimated by the Coal Controller that if only 10 cwt. extra per man per week were produced, an increase of 10,000,000 tons per annum would result. Surely they were entitled to appeal to the miners to put in good and conscientious work to support the men at the front.

CORROSION OF BRASS TUBES FOR CONDENSERS.—Two cases of condenser tubes of brass, which had badly been corroded by electrolysis, were examined by the Materialprüfungsamt, near Berlin, in 1916. The one brass originally contained the following percentages of metals: Copper, 70·5, zinc 28·8, lead 0·21, tin 0·28, iron 0·08; the corroded alloy contained: copper 97·4, zinc 0·69, lead 0·06, tin 0·46, iron 0·08. In the other case the original analysis yielded the following percentages: Copper 59·2, zinc 40·37, no tin, iron 0·32, lead 0·24; the corroded alloy had the composition: copper 96·76, zinc 1·29, no tin, iron 0·10, lead 0·05. In both cases hence the corrosion had bleached out the zinc, and had also diminished the small percentage of lead, whilst there was little or no change in the iron. That the ordinary water of the supply main may give rise to considerable differences of electric potential is shown by the water of Charlottenburg, a suburb of Berlin. In this water couples of zinc and brass acquire a potential difference of 0·888 volt; in view of the actual wide uses of substitutes for metals and alloys, the Prussian Government has drawn attention to this danger of electrolysis.

THE TRADE OF HONG KONG.—In the course of a recent report, Mr. George E. Anderson, the United States Consul-General, points out that the war in Europe has been the chief factor in shaping the course of Hong Kong's trade in 1917, says *The London and China Telegraph*. The high exchange value of silver and the diminishing service of coastwise and oversea shipping, direct results of the war, have had much influence upon foreign trade; but on the whole the year was not a bad one for Hong Kong industries and commerce. Ship-building and sugar refining, which are among the principal industries of the colony, did very well. The shipyards worked to their full capacity, the only limitation being the difficulty of securing materials for certain purposes. The volume of business was far below normal, not only because of the shortage of shipping and high freight rates, but also because of closed markets to Chinese produce in Europe and because of high prices for foreign goods everywhere. Political troubles in China, the reduced buying power of the people, due to a failure to sell their own products at an advantage, and other elements combined to reduce the import trade. Nevertheless, most imports were made upon a rising market, and were therefore more than ordinarily profitable, while exports of some lines of goods needed more or less directly for war purposes, and therefore demanded at almost any price, continued in spite of every disadvantage. The chief feature of trade in 1917 was the predominance of American imports and exports. The closing of many European ports to Chinese produce by the war and the strong demand for raw products in the United States made heavy exports to the latter in certain lines inevitable. The restricted credits both in Hong Kong and in the interior of China and the cost of remittances emphasise the need of an adequate banking system for China. Until such a system is actually established, ordinary trade in this country can scarcely proceed upon reasonable, safe, or satisfactory lines.

THE BUILDING OF REINFORCED-CONCRETE SHIPS.

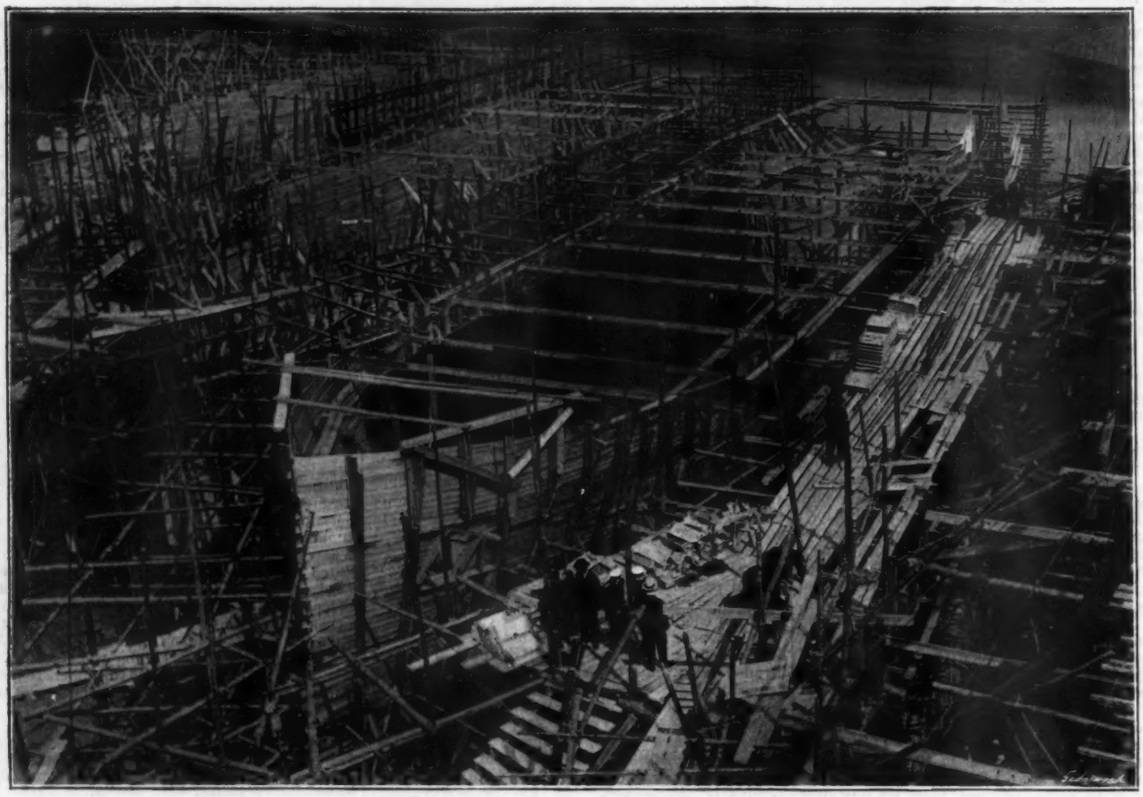


Fig. 1. General View of 1000-Ton Reinforced-Concrete Barges in Various Stages of Construction.

Since attention was first directed to the development of concrete shipbuilding, British naval architects and ferro-concrete engineers working in collaboration have made considerable progress in the practical application of the experience furnished by the construction and behaviour of pioneer vessels built at various times within the past seventy or more years.

Reinforced-concrete shipyards have already been established at various points on the East, South and West coasts of England and Wales, as well as in Scotland and Ireland. Altogether many large reinforced-concrete vessels are now, or soon will be, under construction, representing hundreds of thousands of tons of shipping, and including cargo steamers of 1,150 tons deadweight carrying capacity, steamships of 750 h.p., and barges of 1,000 tons deadweight capacity.

The vessels are built on bilge and keel blocks as in the case of steel ships, and the first operation in every case is the erection of framework and shuttering as illustrated by Fig. 1, where the timbering for four barges is to be seen in various stages of construction. A portion of the shuttering is shown at closer quarters in Fig. 3, page 118.

It should be explained that only the outer shuttering, or outer side of the mould, for the concrete face is completely erected in the first instance, the inner shuttering being built up progressively as the concrete is deposited and tamped around the reinforcement.

Fig. 2 is a view taken in the interior of a barge showing the steel bars and links in process of being assembled ready for adjustment and fixing securely in their positions, the transverse bars being those forming the main reinforcement of the beams extending from side to side of the vessel.

A better idea of the construction is given by Fig. 4, page 118, where some of the reinforcement for the sides of the barge may be seen at the left hand. This view also shows the mould for the transverse frames which are carried along the bottom and up the sides of the vessel, and in the middle some men may be seen assembling the reinforcement of one of the bulkheads.

In some yards the concrete is hoisted to the top of a construction tower 90 ft. high, where it is tipped into a main shoot and distributed by gravity to various points in the barge by means of six branch shoots with a fall of 1 in 3, being delivered upon platforms where the material is turned over by shovel before being deposited in the moulds. As the concrete is of fluid consistency this method of distribution is quite practicable and has given very satisfactory results.

Business men in England were not slow in taking up this new idea in shipbuilding, for within a few weeks after the decision of the Government to commence reinforced-concrete shipbuilding, between 70 and 80 slipways were laid down, and waste lands and barren stretches of foreshore are now busy hives of industry and at the present moment vessels of 1,000 tons deadweight capacity are nearing completion at numerous places in England, Scotland and Ireland. These vessels will soon be following each other into the water in quick succession, and will in turn be followed by others of equal dimensions which will be completed with greater rapidity than the pioneer vessels, owing to the fact that the timbering and shuttering are now available for immediate use without the inevitable loss of time which occurred in the preparation of the first sets.

THE GERMAN IRON INDUSTRY.

A report from the Rhenish-Westphalian iron district states that all the works are being kept employed on heavy army requirements. Yet a change has occurred within the last few months, as far as several works are concerned, owing to the cessation of hostilities in the East, but the expectation that this would mean some material being rendered available for the general demand has so far not been realised. The official permit system is still in force as regards the iron works themselves, the trade, and the direct consumer. Negotiations, however, are proceeding which may result in a limited quantity of iron shortly being sold free, principally for building purposes, so as to give an impetus to the private building industry which has been reduced to a minimum during the war. It will, at best, only be a question of small quantities; unless, indeed, the capacity of the works is increased in the near future. The working of numerous concerns, on the other hand, has, until quite recently, been seriously impeded by reason of shortage of raw material, especially coal, and temporary reduction of output; in some cases a complete closing down of plant has been the result, in consequence of which many works are considerably behindhand with their deliveries. Owing to a more adequate supply of rolling-stock the coal supply, however, has quite recently shown some improvement. There are prospects of the works ere long receiving not only their current requirements, but also some coal for stock, so that their working may soon become normal. The present undelivered contracts appear to be considerable almost everywhere, more especially perhaps as regards rolled products, for which orders many months old are awaiting fulfilment.

There is, further, the question of the revision of prices. The works point out, that the maximum prices for by-products have not been raised since July 1, 1917, so that they no longer correspond with the materially increased cost of production. The authorities seem disposed to meet the demand for higher prices, as far as certain products are concerned, but their decision will, to some extent, depend upon the quotations for coal and coke. On the whole, however, there seems no doubt that the peak has been reached as regards prices on the iron market, and that the military authorities will only grant a further rise, where special conditions justify it.

During the last few weeks the works of the Steel Union have again been considering the question of the prolongation or renewal of the Union. The temporary arrangement expires at the end of the present year, and it is no doubt owing to "pressure from above" that the matter has now been taken up, on the basis of a limitation of the allotments compared with the production of raw steel before the war. An increase in production during the war owing to new extensions of the works is not to be considered. The question of a prolongation of the Union in its present form, the question of the by-products remaining still unsolved, appears to be still in suspense. The representatives of the different works have certainly expressed their usual readiness to assist at arriving at a solution of this problem, but they have at the same time put forward so many separate conditions and desires, that the different committees will have all their work cut out to put all the various requirements in an acceptable form. Most experts appear to hold the view that the restoration of peace and the first few months of the reconstruction period must have been gone through, before the question of the unions within the iron industry can be definitely disposed of. In the meantime, provisional arrangements will have to be resorted to.

With regard to the present position of the iron industry, it may be noted that the production of iron ore has somewhat increased compared with the last few preceding months. Sales for the second half year, therefore, are likely to be on the basis of present prices; the stocks available are limited. The production of pig-iron, especially high grade, is on the whole being maintained

THE BUILDING OF REINFORCED-CONCRETE SHIPS.

(*For Description, see opposite Page.*)

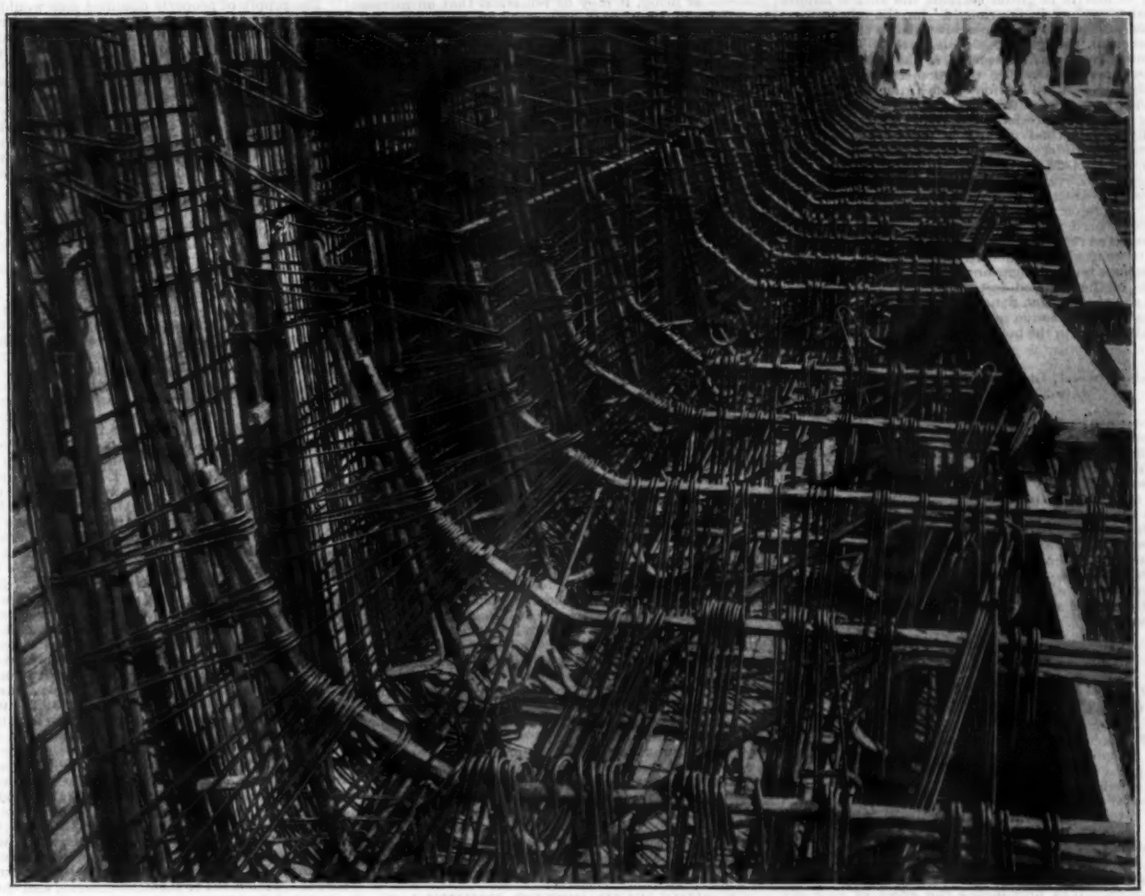


FIG. 2. INTERIOR VIEW SHOWING STEEL BARS ASSEMBLED READY FOR ADJUSTMENT.

at 60 per cent. of the normal, the blast furnaces having been favoured as regards the supply of fuel. Contracts are still made from month to month. Within the Steel Union some modifications have taken place in the production. The works have in hand from the military authorities considerable orders for railway material, which have to be dealt with as urgent war requirements and take precedence over the Union's other contracts. As a result, there is again a scarcity of half-finished products, which is all the more inconvenient for the rolling mills proper, as there is hardly any free material coming forward on account of the high consumption of the steel works themselves. The same may be said to apply to shaped iron. By-products continue to be in strong demand, and for wire and the thinner classes of plates the works have orders which will tax their full capacity for seven to eight months, at least. The terms for specifications have, consequently, become more stringent; some works are entirely unable to accept fresh orders.

The works making structural products have recently experienced some falling-off in their business, since permits for works extensions and new buildings are only granted in the most urgent cases; but there is much activity in bridge and wagon construction. Both the foundries and the metal works exclusively working for the army are fully employed, the latter are full up with orders for many months to come. The position within the small iron industry of West Germany is favourable, and the anticipated greater activity in the building industry will bring increased activity, all stocks in this industry being completely exhausted.

The export business to foreign neutral countries would, no doubt be materially larger, were it not a question of first satisfying the strong home demand. Still, fair quantities are available for that purpose, and there are negotiations pending with several neutral countries concerning fresh agreements, which negotiations also cover the question of a rise in the export prices.

PERSONAL.—The Brightside Foundry and Engineering Company, Limited, Wicker Iron Works, Sheffield, inform us that Mr. Frank Biggin, who has been associated with them for thirty-six years, has been appointed a director of the company.

NORWEGIAN STATE AID TO IRON AND STEEL WORKS AND ROLLING MILLS.

THE war has taught most countries how desirable it is to render themselves as independent as possible of foreign supplies, and in Norway the question has been taken up in earnest. It has several times been urged that the Norwegian State ought to aid in this respect, and a report recently completed by the Industrial Supply Department favours this view. The report says that the State can hardly avoid giving a helping hand in some form or other, if the plan of constructing iron and steel works and rolling mills on a large scale is to be realised.

A premium on production for a certain number of years is the system which in the first instance commends itself to attention. This premium should presumably be somewhat higher for concerns based upon the exploitation of ore than for those which use scrap iron. If the premium to the former is put at 8 kroner per ton of rolled iron and steel, it ought not to be more than 6 kroner for the latter. Further, rolled products of particularly thin dimensions should be entitled to a higher premium.

Direct State subsidies outside the above-mentioned premiums, or a guarantee for a certain percentage on the undertaking, cannot be recommended unless in exceptional cases; such, for instance, as special productions of particular importance to the country from a military point of view, and which are not likely to be taken up unless State aid is forthcoming. Guarantee for loans should only be granted on the express condition that the borrowing concern can offer such security that the guarantee does not involve the State in risk.

On the basis of the principles set forth above, the department proposes the following State aids: To the Christiania Steel Works, 6 kr. (6*s.* 8*d.*) per ton of sheets, and a State guarantee for a loan of 6,500,000 kroner; to the Norwegian Rolling Mills Company, 15 kroner per ton of sheets up to 1 mm. in thickness; and to the projected works at Sandviken and Narvik, when started, 8 kroner per ton of steel products when the production is based upon iron ore in connection with pig-iron production. As a general rule, the production premium would only be paid on products consumed within the country, and subject to the dividend on the shares in the companies being limited to an average of 1 per cent. above the discount, writings-off having been provided for according to official regulations, the average dividend being taken for a period of five consecutive years.

In connection with the above a few particulars on the Norwegian Rolling Mills Company's new works, which are now approaching completion, may be of interest. The works are situated at Simonsvik, near Bergen, and comprise six large continuous shops which constitute the largest covered area in Norway. The plant consists of about 40 electric motors, having a capacity up to 500 h.p.; the current pressure is 7,200 volts. A commodious harbour is connected with the works, deep enough for steamers of several thousand tons. There are excellent modern residences for staff and workmen. The production is calculated to reach 18,000 tons annually at first, principally intended for the canning industry, but it will also comprise heavier sheets, both black, tinned and galvanised. The import to Norway of tinned and galvanised sheets has increased considerably of late years, being 8,000 tons in 1908, 32,000 tons in 1912 and 41,000 tons in 1915, but has again receded on account of the war. The company was formed in 1916, with a capital of 2,000,000 kroner, which has since been increased to 3,000,000 kroner, fully paid-up, and all the shares have to be held by Norwegian citizens.

NON-FERROUS METAL INDUSTRY ACT, 1918.—The Board of Trade give notice that they have extended the time within which the business of winning, extracting, smelting, dressing, refining or dealing by way of wholesale trade in metals or metallic ores to which the above Act applies may be carried on as respects those individual firms or companies whose application for a licence is received by the Board before August 6, but to whom the result of their application has not been communicated by that date, until such time as they are informed of the decision of the Board. The extension of time is granted only because so many applications have been recently received that it is impossible to deal with all cases by August 5. In no case will any application for a licence be entertained which is not received by the Board on or before August 5.

STRESS IN GIRDER SECTIONS.

To the Editor of Engineering.

Sir,—Referring to the review on the new book, "Graphics and Structural Design," by H. D. Hess, in Engineering, dated May 11, 1917, the following interesting comment is given: "In estimating the moment of inertia in girder sections the author adopts the usual procedure in figuring 'I' for the net section, holes being deducted. There is involved in this method a fundamental, though not serious, error. That which determines stress in such a section, at the holes, is rather the stress correspondent to the moment of inertia of the contiguous unholed section of the girder, which stress is amplified by loss of section at the holes. The stress so resulting may be materially different from that ascertained by the method usually adopted. In the case considered, the difference is small in a safe direction, though in other cases the error may be material and give an exaggerated value." The method adopted by Mr. Hess of deducting the moment of inertia of the holes is in common use among structural engineers, and I shall be pleased if the writer of the above review, or other interested reader, will give an opinion regarding the method to be used in calculating the stress in compound girder sections built of joists and plates. If the moment of inertia of the unholed section is calculated and the rivets in the compression flange assumed to fill the holes, as is usual in compression members, how is the stress at the rivet holes and in the bottom flange plates computed?

Yours faithfully,
A. Dickson.

37, Isabella-street, Old Trafford, Manchester,
July 22, 1918.

The treatment of such a section as Mr. Dickson indicates would, with respect to the outer plates of the bottom flange, be first the determination of stress for the unholed section, which result would be multiplied by the gross width over the net width.

Stress at the outer fibres of the joint flange should be tested on the same principle, as the relation of gross to net width may there be less favourable.

The method advanced is based on the assumption that there is a simple increment of stress at the holes in the tension flange, due to reduced section—known not to be strictly true—but conformable to common practice in dealing with holed sections of other tension members of ductile material.

The Writer of the Review.

"COAL SAVING BY SCIENTIFIC CONTROL OF STEAM BOILER PLANTS."

To the Editor of Engineering.

Sir,—The articles under the above heading which appeared in your issues dated July 12 and 19 give an interesting analysis and tables of results in connection with boiler efficiency, but the author appears to have overlooked or at least not given due prominence to the point of rate of evaporation with regard to heating surface.

If the author has the necessary data available as to the extent of heating surface in the various boilers under the several classifications of tests—figures would be interesting by bringing into prominence the effect of rate of evaporation expressed as pounds of water evaporated from and at 212 deg. per hour per square foot of heating surface on the boiler efficiency expressed as pounds of water evaporated from and at 212 deg. per pound of fuel as distinct from the rate of combustion expressed in pounds of fuel per hour per square foot of grate surface.

Yours faithfully,
Glasgow, July 26, 1918. J. W.

To the Editor of Engineering.

Sir,—The article by Mr. Brownlie under the above heading, published in your issues of July 12 and 19, would seem to call for some words of criticism, since, although the article certainly contains some interesting facts, the method of their presentation is unsatisfactory and may easily lead to considerable misconception.

It is a pity that the author, when he was urging the need for more scientific control of boiler plants, did not adopt a more scientific method of tabulating the statistics on which he bases his argument. To take the figures of 250 tests of boiler plants, varying in size from one small vertical boiler to thirty-five 30-ft. by 8-ft. Lancashires, add these figures, divide the sum by 250, and give the quotient as the average working conditions of British boilers is a procedure which will by no means appeal to anyone having the least knowledge of statistical science. Such a crude "average figure" does not correspond to any real quantity whatever, and is, in fact, no more than the result of an arithmetical operation which cannot be used correctly as the foundation of further argument. It is stated, for instance, that the average calorific value of the fuel used is 11,822 British thermal units per pound. This figure may be a close approximation to the true average, but, as equal weight is given to the very small and the very large plants, there is no guarantee whatever that it really is so. The same remark applies to many other figures in the table of the "average" working day's test; for instance, the temperatures of feed water and of steam (saturated and superheated), steam pressure, and the thermal efficiency (total and subdivided). With regard to the latter, the figures given in the table for economisers and superheaters are quite misleading, the so-called average being got on the whole 250 plants, whereas (as stated in the second part of the article), 95 plants had no economisers and 170 plants had no superheaters, only 25 plants being completely equipped with superheaters. The result in the table is the statement that the superheater adds (on the average) only 16 deg. F. to the steam temperature and 0·51 per cent. to the thermal efficiency. Figures like this are useless as a guide in deciding on the value of superheaters in a boiler plant, and it is not easy to see that they serve any other purpose.

With regard to the author's comments on the use of mechanical firing, it may be remarked that an increase in efficiency from 57·8 per cent. to 61·4 per cent. corresponds to a saving of 5·86 per cent. in fuel, which is well worth saving. Also, it is not sufficient merely to compare thermal efficiencies obtained with hand and with mechanical firing; other factors must be taken into account. For instance, it is quite common, when mechanical stokers are installed, to replace a high and expensive grade of fuel by a lower grade, sometimes even using what may be classed as "refuse fuel." Such a change may give a very large saving in cost, but it certainly tends to reduce the thermal efficiency of the plant. In most cases, mechanical firing with an efficient self-cleaning furnace, is essential for the use of the low-grade fuel, because hand firing on a stationary furnace cannot burn it in sufficient quantity to produce the steam required from the boiler, nor can this system of firing deal with the clinker residue.

In the table on page 56 (July 19) giving results classified according to different industries, it is stated that in 22 explosives factories the average weight of coal burnt per boiler per hour is 220 lb. This figure is certainly wrong; it is less than one-third of the next lowest (661 lb.) which applies to lace mills.

Several other points in this article lend themselves also to criticism, and it may be said, to sum up, that, while no objection need be taken to the author's statement that boiler efficiency in this country is poor and should be improved, yet he gives no sound basis for judgment concerning either the extent of the improvement obtainable, or as to the lines along which it should be sought.

Yours faithfully,
G. A. Rossetti.

Bolton, July 31, 1918.

To the Editor of Engineering.

Sir,—In reply to the letter of your correspondent, Mr. Edward C. Barton, in the issue of July 26, 1918, I hope to be able to write before long a series of short articles, each article to consider in detail some special points in connection with the original article "Coal Saving by the Scientific Control of Steam Boiler Plants." One of these articles will deal at length with the performance of the economiser plant of 155 separate boiler plants.

With regard to the question of draught, this was taken at the foot of the chimney by inserting a ¼-in. pipe into the chimney at right angles, so that one end of the pipe reached the centre of the inside of the chimney, whilst the other end was connected to an ordinary water gauge. In the case of induced draught, the pipe was inserted in the centre of the suction of the fan.

Yours faithfully,
(For Brownlie and Green, Limited),
D. Brownlie, Director.

Laboratories and Testing Station, Church-street,
Cheetham, Manchester, July 30, 1918.

A SIMPLIFIED COSINE FORMULA.

To the Editor of Engineering.

Sir,—It is well known that any angle of a triangle can be calculated from the formula

$$2\,b\,c\cos a = b^2 + c^2 - a^2,$$

where a, b and c are the lengths of the sides, and a is the angle opposite the side whose length is a. But this formula is troublesome to apply, unless a, b and c happen to be very easy numbers; and I have seen several methods of turning it into a more convenient shape. None of these, however, is so simple as the one I have recently arrived at, which will doubtless be found useful by some of your readers.

Noting that the second member of the above equation will become the difference of two squares if we add $2\,b\,c$, we can write

$$\begin{aligned} 2\,b\,c\,(1 + \cos a) &= (b + c)^2 - a^2 \\ &= (b + c + a)\,(b + c - a) \\ &= p\,(p - 2\,a) \end{aligned}$$

where p is the perimeter of the triangle. This gives us the very convenient formula,

$$1 + \cos a = p\,(p - 2\,a) / 2\,b\,c,$$

which is easily remembered or re-derived from the well-known but inconvenient one. The necessity for subtracting 1 after finishing the slide rule or logarithms work will not cause any difficulty; for if we temporarily forget this, we shall at once be reminded of it, by the obvious fact that the result so far arrived at is not the cosine we require; and the matter can then be put right in a moment.

Yours respectfully,
W. F. Dunton.

165, Tamworth-road, Newcastle-on-Tyne.

ENGINEERING AND EDUCATION.

To the Editor of Engineering.

Sir,—I write to express my appreciation of the broad principles established by you in your article on the above subject, in your issue of the 19th inst.; principles which are well consistent with the traditions of your journal.

The suggestion with regard to officers returning from the war is particularly welcome. These men will always have the fullest respect of their students, a factor which is essential to real education.

In contrast to your views was that expressed by education authorities through the medium of your advertisement columns.

The salaries offered by these for the qualifications required, namely, full technical training, works experience and teaching experience, would render offers of posts as technical teachers to returning officers quite the opposite to rewards "for services rendered."

The supply of properly qualified men would be assured only if the emoluments were made sufficiently attractive. This will necessarily involve a temporary sacrifice of technical men on the part of present engineering employers.

A case has recently come under my notice of an elementary teacher receiving 130*l.* per annum before the war, who, being invalided from the Army, has since received 6*l.* to 7*l.* per week as a progress clerk, although without previous experience of engineering works. Such men as he are continually being lost to the profession; more so, too, in the higher ranks of technical work.

I am, Sir, yours truly,
S. J. Davies, Wh.Ex., A.M.I.Mech.E.

21, Copthorne-road, Wolverhampton, July 26, 1918.

GERMAN WAR PROFITS.

The report of Felten and Guilleaume, Carlswerk, Cologne, Mülheim, states that all departments had been fully employed, and that the increased turnover had made up for the less remunerative prices. The affiliated concerns and the shares held by the company had also yielded correspondingly satisfactory results. The dividend for last year was fixed at 15 per cent., against 12 per cent. for the previous year and 8 per cent. for the last two peace years. The net profits amounted to 9,983,942 marks, against 7,895,215 marks for 1916 and 5,176,443 marks and 6,031,788 marks respectively for 1912 and 1913. The writings-off for last year amounted to 4,875,542 marks, against 1,726,166 marks for 1913. For war aid 2,327,733 marks were reserved out of last year's profits. Owing to the share capital of the Steinfor Iron and Steel Works having been raised, the company's contribution to this concern had been correspondingly increased. In order to secure the adequate supply of fuel the company had secured shares in the Oldenburg Peat Company, Romsloh, and in the Liblar lignite mines and briquette factory. In order to ensure a supply of articles of food to their employees the company had opened up connections with agricultural concerns. Apart from land, buildings and war installations, all other costs had been completely written off, whilst machines, &c., in the last balance-sheet still figured for a sum of 2,350,000 marks. The holdings of stocks, war loan, &c., had risen from 33,320,000 marks to 39,250,000 marks. The share capital was 60,000,000 marks and the reserve fund remained unaltered at 6,000,000 marks.

The firm of Orenstein and Koppel—Arthur Koppel—earned last year gross profits of 21,913,070 marks, about the same as the previous year, whilst the revenue from affiliated companies rose from 1,315,117 marks in 1916 to 2,178,181 marks for last year. On the other hand, expenses rose from 12,180,970 marks to 16,216,879 marks, but this was somewhat counterbalanced by writings-off being reduced from 4,867,002 marks in 1916 to 1,344,278 marks in 1917. The surplus, including a sum carried forward, amounted to 9,569,907 marks, and the dividend was fixed at 14 per cent., against 12 per cent. for the previous year. The turnover, including that of the affiliated companies, but exclusive of the branches in hostile countries and such neutral countries with which the mail service is interrupted, amounted to 120,483,329 marks, against 92,540,906 marks in 1916. The company had orders in hand which would keep it fully employed to the end of the year.

The shares of the Hamburg–South America line have recently experienced a substantial rise, the company having sold a 9,000-ton steamer in Argentina, it is understood to the Argentine Government. The price was 12,000,000 marks, and negotiations are stated to be pending for the sale of other of the company's boats laid up in Argentine ports.

Feedwater Preheaters on Railway Engines.—A series of experiments with preheaters and pumps for the feed water of locomotive boilers are described by Dr. L. Schneider, of the Maffei Locomotive Works, Munich, in the *Zeitschrift des Vereines Deutscher Ingenieurs* for May 11 and 18, 1918. Experimental runs were made on a railway section 62 km. (40 miles) in length, partly inclined. Three feed-water preheaters of different constructions and two piston pumps were installed on the engines and tried, and from the experience gained an improved fourth type of preheater was designed which gave good results. It is pointed out that the water flow through the preheater should be rapid, and that the exhaust steam introduced into it should be of high pressure.

Wolfram Discovery in Queensland.—The Queensland Department of Mines has received a report from the Acting Warden at Port Douglas on the recent discovery of a lode of wolfram in the district. The country where the mineral has been discovered is unsurveyed and hitherto unprospected, comprising dense tropical scrub on the eastern slope of the main coastal range at the head waters of the Little Mossman River. There is no access to the country except by tracks cut by prospectors. The distance is estimated at 12 miles from Mossman, 24 miles by road from Port Douglas, and 12 miles south of Mount Molloy. The warden states that he has obtained specimens, and has sent them to Brisbane for assay. The original prospectors are very optimistic, and estimate that there are at least 3 square miles of metalliferous country in the locality.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Work is once more in full swing, although, as is usual after the Fair Holidays, it took some of the men a few days to make up their minds for a restart. Now, however, all are working as briskly as ever, with no other thought than the speeding-up of output. There is little doubt but that this should be a comparatively easy matter, owing to the very considerable amount of repair work put through during the time the men were on holiday. The strain on plant and machinery, since the last repairs were executed at the New Year holidays, has been severe in the extreme, so that the necessity of a complete overhaul was too obvious to be under-estimated. Orders, chiefly on Government account, have simply flowed in, so that, with augmented facilities of production, steel manufacturers are able to guarantee constant employment to their staffs, and as speedy a delivery as possible to their customers. Munitions of every description are still in such active demand that little material is available for any other purpose. Were better deliveries of raw material possible a considerable development of output might be assured.

Malleable Iron Trade.—In the malleable iron trade conditions of extreme activity again prevail, and with all machinery running smoothly after its much-needed overhaul and repair, a greatly increased output is being looked for in the immediate future. Supplies of raw material are still rather uncertain through lack of adequate shipping facilities, but recent developments which have taken place seem to point to a solution of this difficulty. Export is practically out of the count meantime.

Scotch Pig-Iron Trade.—The incessant demand for pig-iron of all grades, notably for hematite for the steel works, continues to be a dominating feature, and every effort is being made to maintain the production at the required level. Work of national importance is constantly on the increase, hence the uncertainty of meeting all the requirements in a satisfactory manner owing to scarcity of raw material and depletion of staffs. Time, however, may rectify these deficiencies. Export is confined to some small shipments for the use of the Allies, and prices, excepting where officially controlled, remain strong.

Ironfitters' Increase of Pay.—The General Ironfitters' Association for Scotland recently made an application for an advance of 100 per cent. on pre-war wages, and the decision arrived at by the Committee on Production has just been intimated. While the advance granted is not as much as that demanded by the Falkirk men, it brings up the increase on pre-war wages to 75 per cent. Men of 18 years and over are to receive 3*s.* 6*d.* per week extra, and lads under 18, 1*s.* 9*d.*, this flat rate applying whether on time, piece work, premium, bonus, &c.; while a corresponding increase will be allowed for overtime, Sunday work or holidays. The advance will take effect as from the pay day of the week ending August 10.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—So far, the expected recrudescence of activity has not materialised. In isolated departments great difficulty is being experienced in keeping abreast of orders, but generally speaking, conditions are decidedly easy. There is a marked slackness at the crucible steel furnaces, employment having fallen to a very low level. There has also been a considerable decline in the calls for high-speed steel, and for tool steel, too, the requirements are only such that they can be very easily met. Unfortunately, operations have not yet been resumed in the iron foundries, the moulders having now been out on strike for a fortnight.

South Yorkshire Coal Trade.—The state of the coal trade does not vary. The whole of the output is absorbed by contract account, and in all sections of the market there is a demand out of all proportion to the supply. The request for best steam hards remains exceedingly strong, the export requirements showing a tendency to increase. Cobbles, nuts and slacks are still very difficult to obtain, and there is no improvement in the household section. Cokes readily bring maximum figures. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—An unfortunate restrictive influence is imposed on the Cleveland iron trade by the shortage of labour and fuel. Deliveries of iron against current contracts are impeded by lack of men, as it is impossible to load anything like all the iron in hand, and the acute situation as regards coke has resulted in some blast-furnaces having had to be put on slack blast. Thus in both volume and quality make is reduced. August allocations of Cleveland foundry iron are now coming forward, but they are on a smaller scale than hitherto, the impression being that rather less iron will be required during the ensuing month; whilst in addition some consumers are understood to be better placed than they have been. The quantity of forge iron on the market is still very considerable despite recent large sales over the next two months. Buyers and sellers continue busy fixing up forward business. The truck supply is good, and all descriptions of pig-iron that can possibly be despatched find a very ready market. As regards export trade, business with France is proceeding steadily through official channels, and now the announcement is made that shipments to Italy are being arranged through the Ministry of Munitions, so that interest of merchants in export trade is now little or nothing. For home consumption, No. 3 Cleveland pig, No. 4 foundry and No. 4 forge, are all quoted 95*s.*, and No. 1 is 99*s.*; and for export, No. 3 and the lower qualities are 119*s.* and No. 1 is 124*s.*

Hematite Iron.—The hematite position shows no change of any moment. A continued very heavy home demand is supplemented by eager inquiries from the Allies, who are keen to take up whatever iron there is to spare; but with such a large proportion of the output required for home purposes, relatively little iron is available for shipment abroad. All absolute home needs continue to be regularly met by the careful system of distribution, under official supervision. Mixed Nos. of East Coast brands are 122*s.* 6*d.* for home use and 147*s.* 6*d.* for export.

Manufactured Iron and Steel.—Producers of finished iron and steel, though hampered by the situation as regards labour and fuel, manage to maintain output on an enormous scale. Prices, all round, are very stiff. To home customers common iron bars are 13*l.* 17*s.* 6*d.*; best bars, 14*l.* 5*s.*; double best bars, 14*l.* 12*s.* 6*d.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel hoops, 17*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.* Export prices are not fixed, but they are approximately 40*s.* to 60*s.* above home quotations.

Coke.—The exceedingly heavy demand for coke cannot be anything like adequately dealt with. Production is affected adversely by the shortage of coal, and the scarcity is becoming more and more pronounced. The supply is from hand to mouth. Average blast-furnace coke remains at 33*s.* at the ovens, and low phosphorus sort at 35*s.* 6*d.* at the ovens.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—There is very little change in the general situation. Practically all the coal is being absorbed by official and home requirements, and there are hardly any free supplies available for ordinary traders. In view of the fact that the miners are going to take three days' holidays next week the shortage of supplies will become still more acute. The first meeting of the Shipping and Coal Co-ordinating Committee has been held, but in view of the exceptional circumstances the Committee cannot be expected to settle down to work for some time to come, and during August, supplies of all sorts of coal will unquestionably be very tight. Erratic stoppages here and there at the collieries add to the embarrassment of the position. To-day, for instance, the whole of the miners at Clydach Vale—about 4,000 in number—took the day off simply because proceedings had been taken against a number of men for breach of contract.

Newport.—Monmouthshire coals of all descriptions are now scarce. The Risca Collieries are still idle, the men hesitating to return to work owing to the discovery of gob fire in an old working in an adjacent colliery. There is a fair supply of pitwood, but coke and patent fuel are scarce.

Coal Trimmers' Wages.—An application has been made by the Cardiff, Barry and Penarth coal trimmers for a further increase of 40 per cent. in war bonus, which at present stands at 60 per cent. over the pre-war level. It is understood that a similar application is being made at other ports in the Bristol Channel. No meeting of the Trimming Board to consider the matter has yet been convened, but it will probably be held at an early date.

Miners' Bank Holidays.—At a meeting of the Joint Board of the Welsh Coal Trade, held at Cardiff yesterday, the men's leaders made an application that the workmen be granted three days' holidays for the bank holiday week. The owners' representatives pointed out that they had received a communication from the Controller of Coal Mines which, they understood, had also been sent to the workmen's representatives, urging that only one day should be taken in view of the present acute shortage of coal, and the owners, therefore, appealed to the workmen's representatives to be satisfied with one day. The workmen's representatives, however, intimated that they had unanimously decided to take three days' holidays, viz., Monday, Tuesday and Wednesday next. In view of this decision, the owners had no alternative, and the days indicated will therefore be observed as holidays in the South Wales and Monmouthshire coalfield.

The Shortage of Coal.—Mr. Finlay A. Gibson, the secretary of the South Wales Coal and Coke Supplies Committee, referring to the decision of the Welsh miners to take three days' holidays next week, officially states that the present shortage of coal is serious, and is at the present time affecting both works and the general public. The result of the collieries being idle three days next week, he says, will mean that there will be practically no supplies of coal available for householders for some time, but neither the Coal Supplies Committee nor the colliery owners will be responsible for this. The Coal Supplies Committee, he adds, have been making every effort to distribute amongst home consumers the available quantity, which is below requirements, but the effect of the three days' holidays will be such that many consumers will not be able to obtain any coal.

CATALOGUES.

Electric Light Fittings.—A catalogue of fittings for industrial lighting issued by the British Thomson-Houston Company, Limited, 77, Upper Thames-street, E.C. 4, is remarkably complete in all varieties of fittings and contains much useful information.

Staff Gazette.—"Callender's Staff Service Gazette" contains many interesting notes from members serving in the war, giving their experiences: 652 employees have joined the Colours, 47 have passed away, and 7 are prisoners. Eight have won decorations. In this case the word "staff" is used in its new democratic sense, as including all the employees.

Lifting Jacks.—A clean-made and serviceable screw jack is shown in a catalogue issued by the British Steel Piling Company (Edward Le Bas) of Dock House, Billiter-street, E.C. 3. The nut is revolved by a worm, the worm wheel being of phosphor bronze and the thrust of the nut taken on ball bearings. The gearing is entirely enclosed except for the part of the screw exposed in the raised position. The standard sizes are for lifts of 15 tons, 25 tons, 40 tons and 60 tons.

Petrol Engine Valves.—The "Duco" valve stem lubricator is a piece of oil-carrying fabric pushed over the stem of the valve and held in place by a coiled spring. It gives way to the reciprocation of the valve and keeps the friction surfaces of the stem continually oiled. With properly selected oil, and kept in order, it should be of great advantage, not merely in reducing friction but in making the valve quickly responsive. Messrs. Brown Brothers, Limited, Great Eastern-street, London, E.C. 2, are the agents. Several good testimonials from users are printed in the catalogue.

Acid Vessels.—A series of cast-iron eggs and stills is shown in a catalogue received from Messrs. Meldrums, Limited, Timperley, Manchester. A horizontal egg with bottled ends and bolted on end plates is 3 ft. diameter and 12 ft. long, to hold 500 gallons. The stills are fitted with single or double stirrers worked by power or hand gear; also with internal heating coils or jackets. Where covers are frequently removed the bolts are let into slots so that they may be slacked and withdrawn radially without running off the nuts. The vessels are made in other metals than cast-iron, and in cast-iron lined with lead, vulcanite or enamel as required for acid contents.

Cranes and Winches.—New editions of their catalogues of land and ship-deck lifting machinery have been issued by Messrs. John H. Wilson and Co., Limited, Birkenhead. These comprise a wide range of powerful and well-furnished machinery actuated by steam or electricity or in some cases by pressure air. They were described in detail in these notes some months ago. A silent steam deck winch has machine-cut gear running in oil baths. A "Portal crane" travels on rails nearly 25 ft. apart spanning two lines of standard track and having all necessary movements—lifting, slewing, travelling, &c.—to make it a self-dependent means of transferring cargo from ship to railway trucks.

Travelling Cranes.—A fine series of these cranes is illustrated in a little catalogue received from Messrs. Thomas Smith and Sons (Rodley), Limited, Rodley, near Leeds. The examples include a 20-ton electric gantry crane travelling on 18-ft. gauge rails specially built for the Admiralty dockyards; several derrick cranes for ordinary rail gauges and two magnet cranes; overhead cranes travelling on girders and a "walking" crane. "Walking" is not a very apt term: it means a crane travelling on a single ground rail and a single overhead rail—an extremely convenient arrangement for warehouses, stores, workshops, &c. The electric cranes have separate motors for the different movements such as hoisting, slewing, travelling and jib-adjusting. The magnet cranes are both steam driven and carry generator sets for the magnets; pig-iron, scrap and hot castings or forgings can be lifted very conveniently with these cranes. The firm, established in 1820, is now a private limited company, and remains under the personal management of the three Messrs. Smith.

Pneumatic Tools.—The pneumatic tool, or air-driven hand machine, is fully holding its own. The new catalogue of the Consolidated Pneumatic Tool Company, Limited, 170, Piccadilly, W. 1, is larger than before with new hammer and drill types of machines and new handle and other fittings making them suitable for ever-extending uses. Indeed there are now a very large number of these machines for special work or, more correctly, for work in specially awkward situations in boilers, ships, bridges, &c. In addition to many riveting, caulking and chipping hammers and drillers there are sand sifters, sand rammers, grinders and polishers, little air power hoists lifting from 1 cwt. to 2 tons and more elaborate hoists, though on a small scale, tube cutters and expanders. A series of four small fixed position air motors are made of 1½ h.p. to 5 h.p. These run in either direction and are instantly reversible. The 1½ h.p. has a 2½-in. cylinder and 2½-in. stroke and 1-in. diameter shaft. It runs 1,100 r.p.m. light down to 660 r.p.m. loaded, and consumes 45 cub. ft. of free air per minute. The weight is 122 lb. Tools for use under water are also shown. The company has works at Fraserburgh, on the East Coast of Scotland, and repair shops and stores in London. The following quotation from the introduction to the catalogue is characteristic of these changing times: "We have spared no expense, not only in installing the best machinery, but by caring for the welfare of the employees, providing reading and billiard rooms, a shooting gallery, and fields for outdoor sports; every encouragement being given to the employee to produce the best article under the most favourable conditions."

THE BUILDING OF REINFORCED-CONCRETE SHIPS.

(*For Description, see Page* 114.)

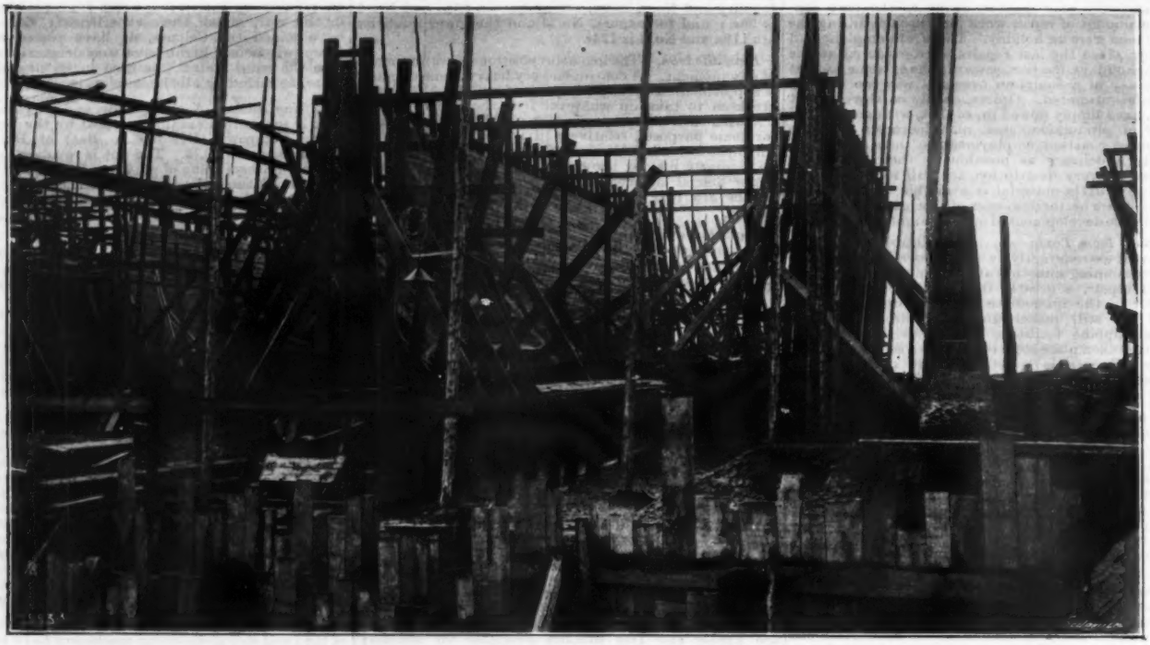


Fig. 3. Erecting the Shuttering for the Vessel.

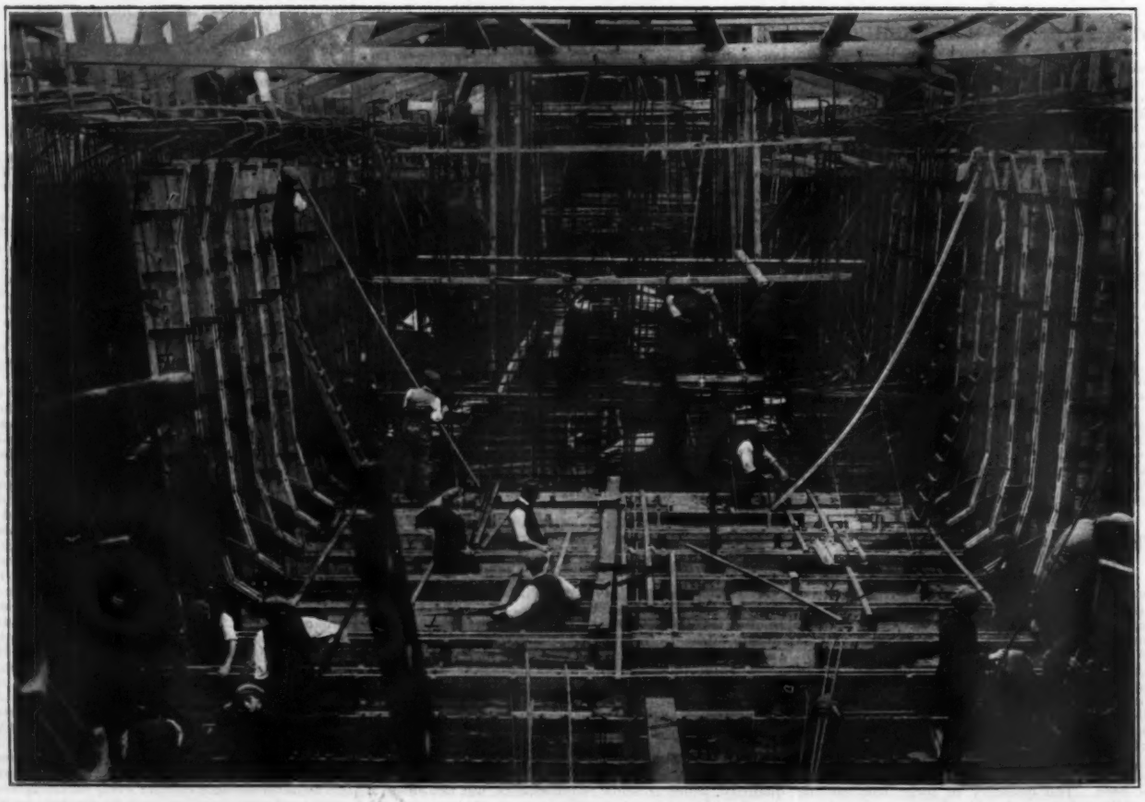


Fig. 4. Steel Fixings and Casings to Receive Concrete, showing Reinforcement of Bulkhead.

WATER-TUBE BOILER PLANT AT THE BRISTOL CORPORATION ELECTRICITY WORKS.

CONSTRUCTED BY MR. JOHN THOMPSON, ENGINEER, WOLVERHAMPTON

(*For Description, see Page* 126.)

Fig. 1.

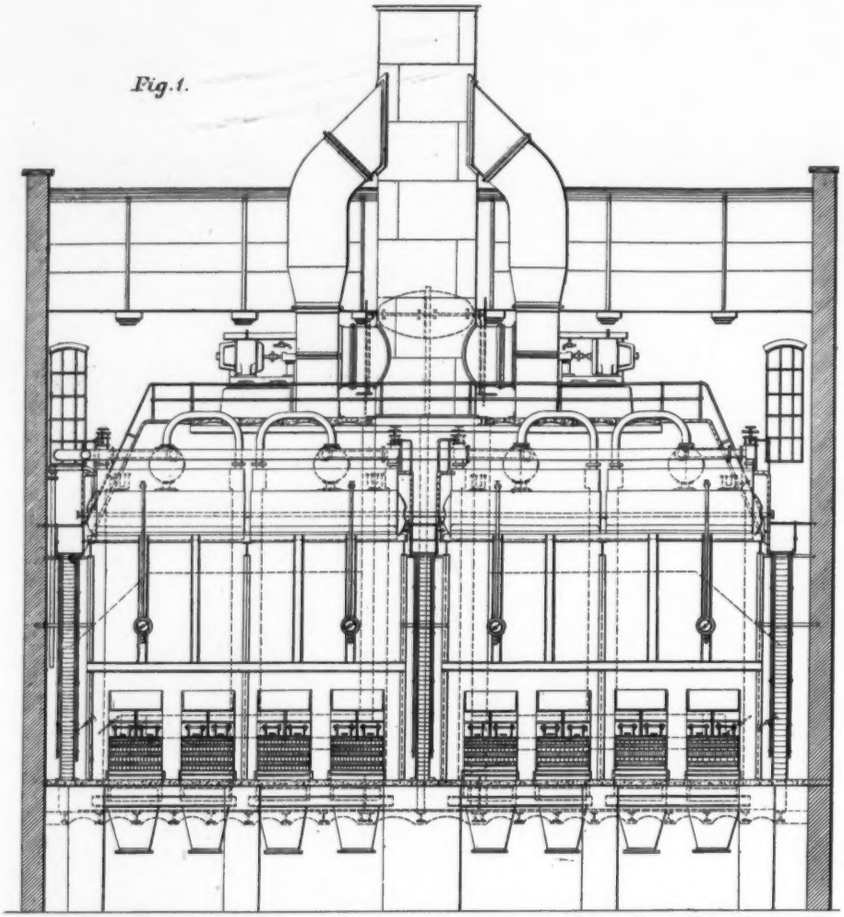
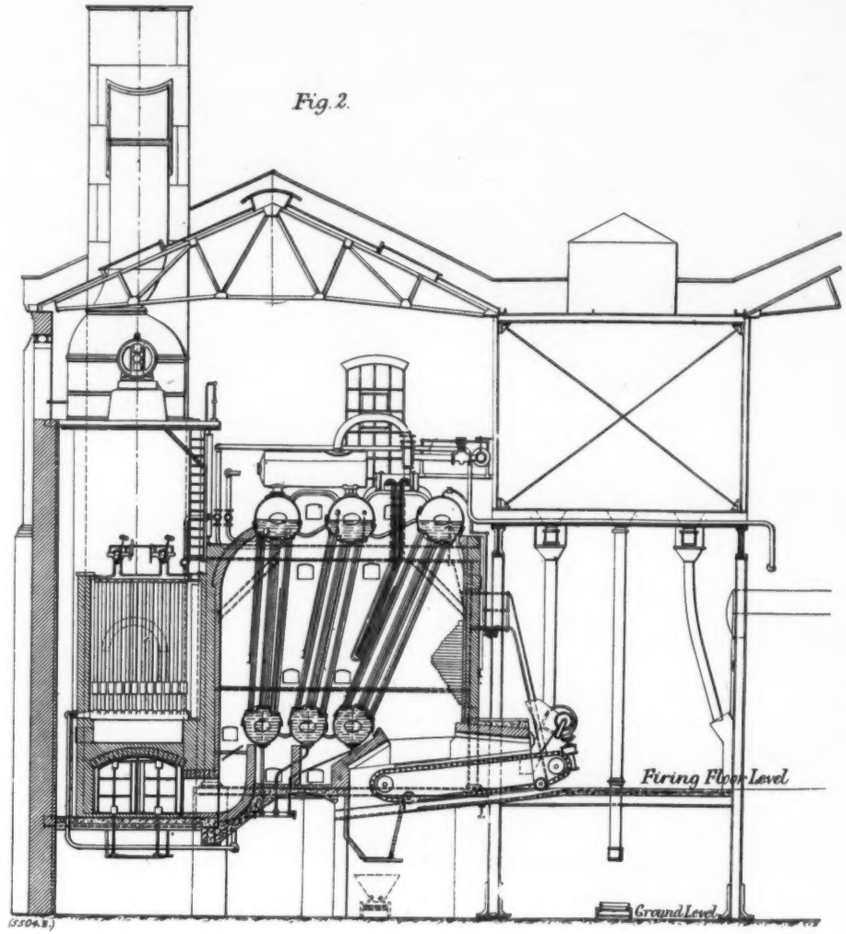


Fig. 2.



(5504.B.)

Fig. 3.

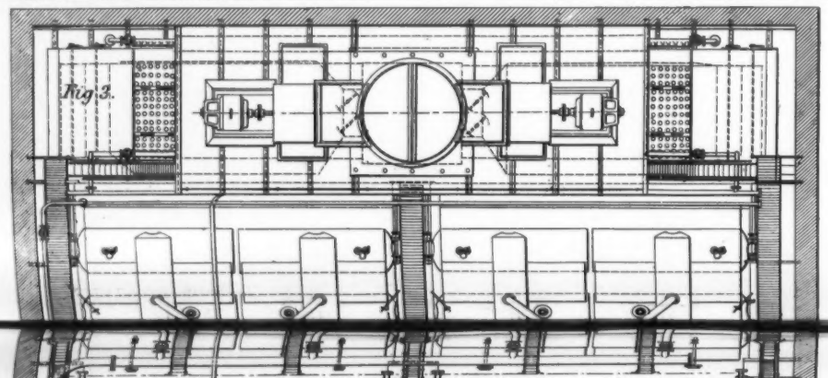
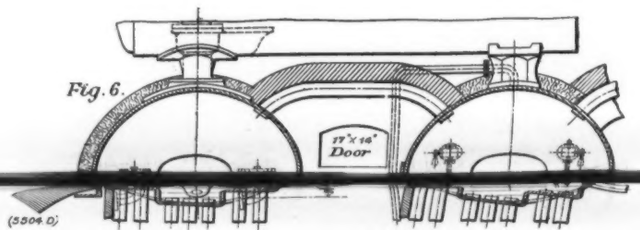


Fig. 6.



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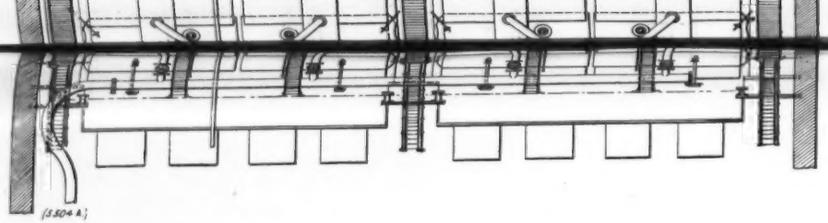


(3504 D)

(3504 A)

Fig. 4.

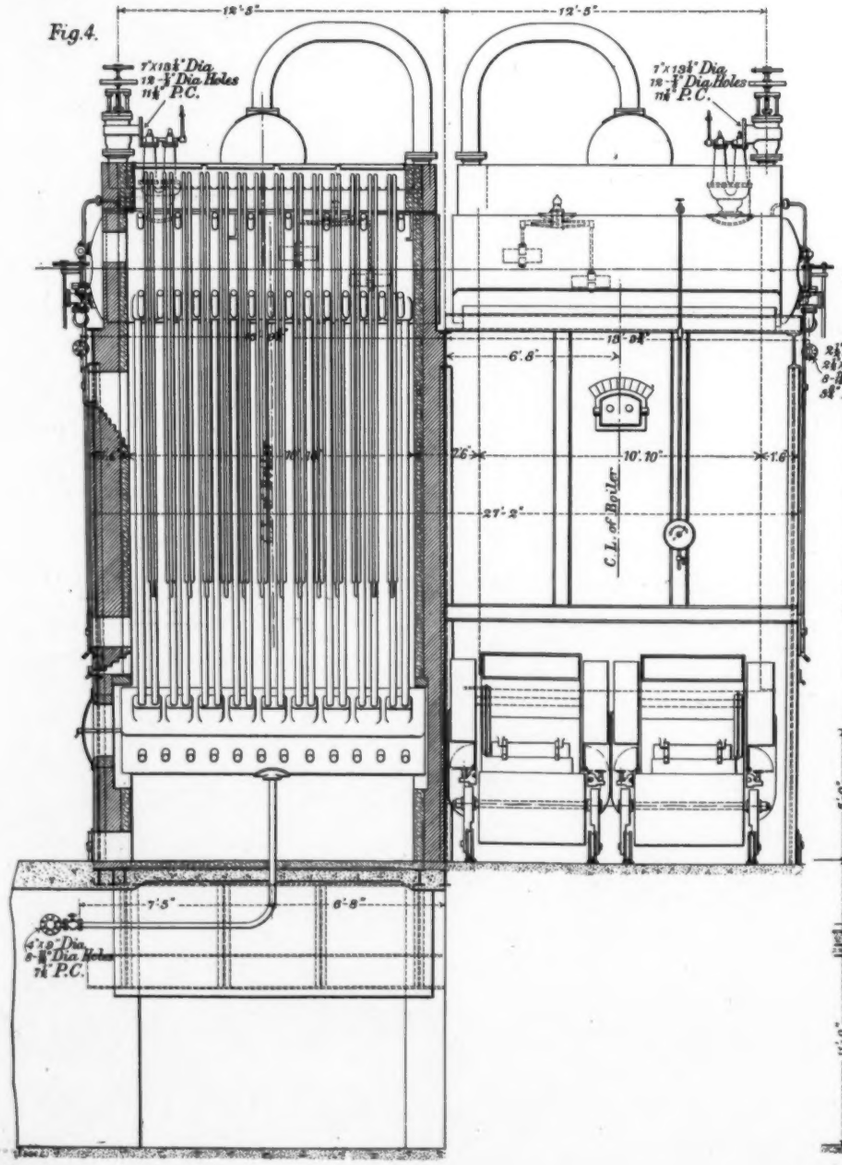
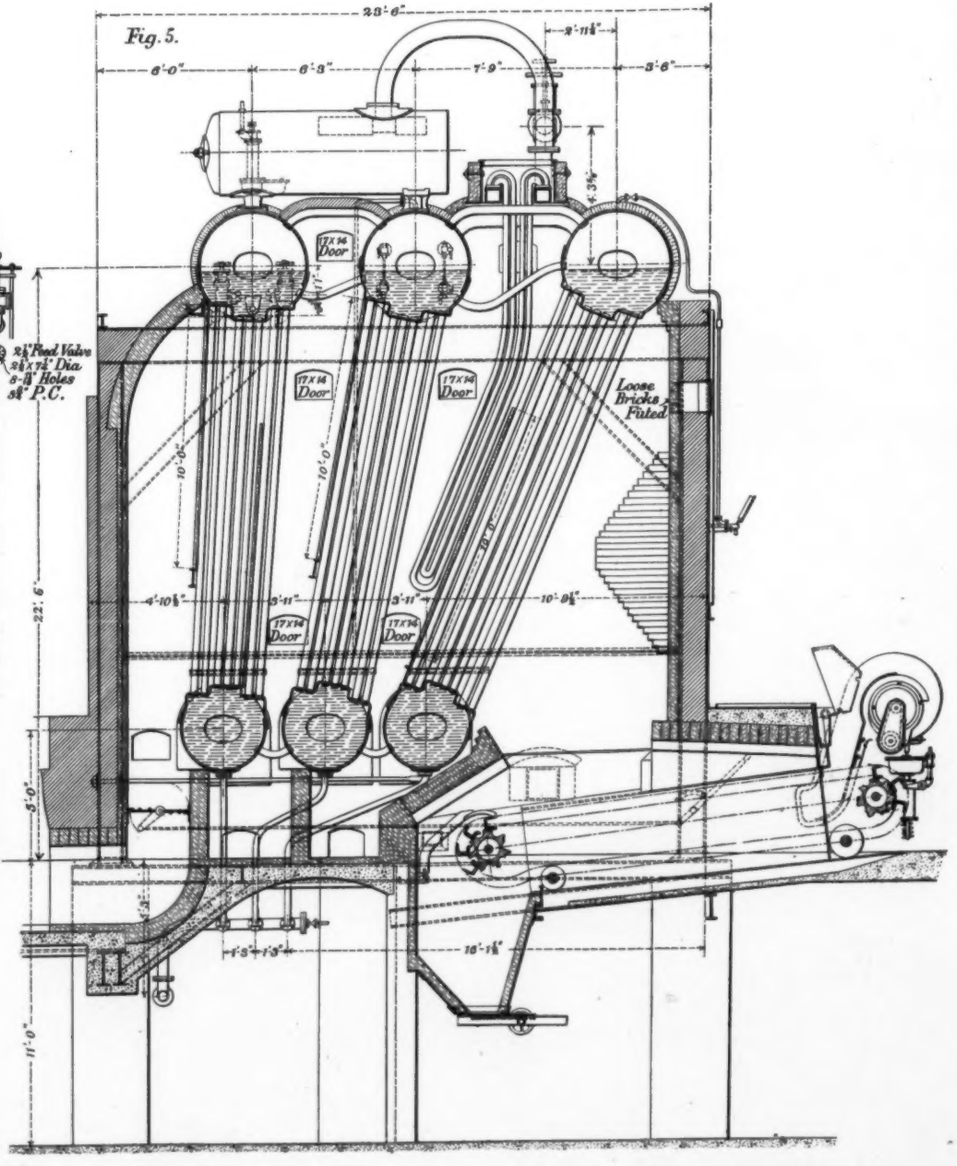


Fig. 5.



AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Turner and Henderson, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
CANADA, Toronto, Ont.: Wm. Dawson and Sons, Manning Chambers. Montreal: Sells, Limited, 302, Shaughnessy Building, McGill-street.
EDINBURGH: John Menzies and Co., 12, Hanover-street.
FRANCE, Paris: Boyveau and Chevillet, 22, Rue de la Banque. For Advertisements, Agence Havas, 8, Place de la Bourse.
GLASGOW: William Love.
INDIA, Calcutta: Thacker, Spink and Co. Bombay: Thacker and Co., Limited.
ITALY: U. Hoepli, Milan, and any post-office.
LIVERPOOL: Mrs. Taylor, Landing Stages.
MANCHESTER: John Heywood, 143, Deansgate.
NEW ZEALAND: Gordon and Gotch Proprietary, Limited, Wellington, Auckland and Christchurch.
NORWAY, Christiania: Cammermeyer's Boghandel, Carl Johans Gade, 41 and 43.
ROTTERDAM: H. A. Kramer and Son.
SOUTH AFRICA: Central News Agency, Limited, Head Office—Johannesburg; and Pretoria, Cape Town, Port Elizabeth, Bloemfontein, Durban, and their various branches and bookstalls throughout South Africa. Also Cape Town: Wm. Dawson and Sons, 31, Long-street.
TASMANIA: Gordon and Gotch Proprietary, Limited, Launceston: Hobart.
UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue.
For Advertisements, J. S. Allan, 508, Stratford Avenue, Bridgeport, Conn., U.S.A.

ADVERTISEMENT RATES.

The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

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With a Two-Page Plate of the WATER-TUBE BOILER PLANT AT THE BRITISH CORPORATION ELECTRICITY WORKS.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

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In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents after June 24th will not have copies for chance customers, therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

ENGINEERING.

FRIDAY, AUGUST 2, 1918.

NATIONAL SHIPYARDS.

ONE more stage in the evolution of the national shipyards was disclosed by the First Lord of the Admiralty in the debate in the House of Commons on Tuesday. It further serves to show that, alike in its inception and its development the scheme has lacked definiteness of plan, and shows evidence of guidance by other than technical and experienced minds. Even at the risk of repeating what we have said at successive stages in the project, we may review the whole history of the undertaking, since there is still justification for doubt whether success can be achieved even under the guidance of such an experienced practical shipbuilder as Lord Pirrie. That ships will be built and completed is certain, because Lord Pirrie is a man who by force of character will attain this result. But, as one of the speakers in the debate insisted, the whole problem is the efficient utilisation of the available man-power. This, we have contended, can best be achieved by the private yards having the first claim on men, whether skilled, semi-skilled or unskilled, and on material. The *raison-d'etre* of the proposal to establish national yards was the utilisation in them of German prisoners of war working under the direction of a sufficient number of skilled artisans from existing yards. But, before the project had got beyond the stage of conception, advice was given by a committee composed of shipbuilders, each of whom had made a great success with his own establishments. They were uncompromisingly opposed to the whole scheme, and so also were the Consultative Committee, composed of trade union leaders. Even commonsense ought to have made those responsible to realise that trade unionists would not work with and guide German prisoners of war. Moreover, all British labour available ought to have gone to the private yards, where there was, admittedly, a grave deficiency in this respect. After much money had been spent on the national yards it was found that trade unionists refused to work with German prisoners of war. In the meantime, however, the work of building hutments and of laying out the ground was being pushed forward, largely by the unskilled German prisoner. The First Lord, however, conceded the view that until the requirements of private yards in the matter of workmen were fully met they would have priority in the engagement of British labour that became available. At the same time the promise was made that 20,000 men would be taken back from the army to supplement the labour in the private yards. Of these some 12,000 men have been brought back, but the assertion is made, no doubt with a large measure of truth, that these men are not fully efficient, due partly to physique and partly to insufficient experience. There has, however, been a continuous drain from the yards to the Army of young men trained in shipbuilding. No doubt the exigencies of war on the western front have made this withdrawal necessary. But the result has been that to-day the number of workers in shipbuilding and marine engineering works is less rather than more, as a consequence of the redistribution of labour.

Another contention in favour of the national shipyards was that they were to be engaged on fabricated ships. The First Lord, in his statement on Tuesday, put forward the plea that private shipbuilders opposed the construction of fabricated ships, just as they had been reluctant to adopt the standard designs of ships. This, however, is only part of the truth. There has been a tendency, probably quite unpremeditated, to confusion in regard to fabricated ships. America took up the fabricated ship with remarkable enthusiasm and with splendid results; but this was due, not to any choice or approval *prima facie* of the system of construction, but rather to the force of circumstances. America had few shipbuilding yards fully equipped with machine tools for the conversion of material, as it arrived from the rolling mill, into the construction of a ship. On the other hand, they had immense establishments with extensive and admirably-designed machinery for converting the same units into bridges, "sky-scrapers," and other constructional steel erections. It was therefore a wise policy to utilise this machinery to construct units of ships as large as could be conveyed by rail and to confine work in new shipbuilding yards to the assembly and riveting-up of these large units in the hull of the ship. There is no need to show that this method cannot be regarded as the most economical, or, indeed, the most efficient, system of building ships, particularly if, as is the case not only here but in America, the railway lines are heavily congested with traffic. Bars, angles and plates can be much more easily and cheaply moved by rail than these large fabricated units, and consequently time, coal and man-power are not so effectively utilised in the building of fabricated ships. In this country, it is true, we also have large bridge-building and other constructional steel works, and it was quite proper that the machine tools in these establishments should be utilised as far as they were available for the construction of the units of ships' hulls. There was, therefore, some measure of support for the construction of yards specially arranged for this work, always provided that such assembly of units from bridge-building works could not be carried out speedily and cheaply in shipbuilding yards. Such work, of course, must necessarily be supplementary to the ordinary building of ships, including the preparation of the bars, angles, plates, &c., by the machinery already installed at these yards. The approval or otherwise of the private shipbuilders was therefore contingent upon the full utilisation of their own machine tools and the engagement of men on fabricated ships in berths which could not otherwise be occupied with the material machined in their own shops. That these private yards are now taking up the work of fabricated ships is proof of the willingness of employers and men to do their best for the nation. In view of this Lord Pirrie agreed, a few weeks ago, that work in the national yards should, for the present, be confined to the organisation and equipment of the yards, and that the available fabricated units from bridge-builder should be sent to the private yards. So convinced was he of the desirability of this course, that extensive supplies which had already arrived at the national yards were, before the work of assembly could proceed, returned over many miles of railway to the private yards. Indeed, certain of the material which was to be used at the national yards was transmitted, in some cases, 200 or 300 miles.

Now the policy has again been changed. The First Lord informed the House that the keel of the first ship would be laid a month hence, and that the work of building the fabricated ships would continue at a rapid rate. There are to-day 10,000 men working at the national shipyards, almost entirely unskilled, except those who have been taught pneumatic riveting on the spot. Of these, 3,000 are prisoners of war—we presume these are engaged on the work of preparing the berths and house-building—while 7,000 enlisted men are to be passed into the reserve, to take up work as civilians at civilian rates of pay. The private shipbuilder is entitled to ask whether this change is consistent with the promise, made repeatedly, that their labour demands for shipbuilding would have priority, and the House of Commons seems sceptical whether these men, who

had been withdrawn from the army, could be as efficiently utilised at national yards as in private establishments. Their protest is the more important because the number of available berths in private yards is steadily increasing. In the first place berths which were occupied from the beginning of the war with ships laid down for private shipowning companies are now being vacated, as permission has been given to complete these ships, which in some cases have been lying for four years without any work being done, notwithstanding that great ships, suitable for use as transports and capable of conveying thousands of troops, could have been completed for a less expenditure of material than the standard ships, and with an absorption of labour not greater than that required for a standard ship of one-third or one-fourth of the capacity. Indeed, in one yard there were, until recently, four magnificent Channel steamers, some of them in the water and some on the berth, for the completion of which authority could not be got. In addition, 87 new building berths, authorised some time ago, are gradually coming into use; many of them are already occupied, and the whole of them will be available in a short time. These berths are more than capable of producing the 3,000,000 gross tons required per annum, according to Admiralty computation of necessary tonnage supply, provided the labour is available. As we have shown, these berths are being completed, while no corresponding increase has been made in the labour supply to private yards. Mr. Runciman made a remarkable contrast between the lack of expedition in the completion of the national yards, which were commenced a year ago, and the very smart work done on the Tees, recently illustrated in ENGINEERING. A yard started last March will, in a week or two, be turning out fabricated ships, whereas in the national yards, after a year's work, the first keel will only be laid in a month.

One further development is that although these national yards were designed for purely fabricated ships, Lord Pirrie has decided that machine shops must be erected to work one-half the material necessary for keeping the 36 berths going, so that step by step the whole conception on which the project was based has been swept away, and we now find that the national yards are intended to be equal with any private yard. Undoubtedly, if they had been confined purely to fabricated ships the end of the war would have deprived them of the units of which these vessels are built, because bridge-builders and constructional steel makers would necessarily have had to give up shipbuilding and turn their attention to that work of reconstructions particularly in devastated countries, for which their equipment is specially devised. Bridge builders will be too busy on their own work to continue shipbuilding work. Thus the national yards, by this latest decision, become a permanent institution rather than a war emergency proposition. It is, as was threatened from the beginning, the thin end of the wedge of nationalisation in shipbuilding, and to this extent ought to be resisted in the most vigorous and conclusive way.

THE EMBARGO STRIKE.

THE ultimatum presented by the Government to the munition strikers has had the immediate effect of bringing about a general collapse of the movement, as was foreseen by all who were familiar with the circumstances out of which the cessation of work arose. The alternative "Either work or fight" was heartily endorsed by the general public, who showed anything but sympathy with the men who, while enjoying privileges of security and comfort far beyond any other class of the community, openly defied the considered decision of the Government as well as the advice of their own leaders. The temper of the public was unmistakable, and one heard a general regret that the ultimatum should have been delayed a moment after the threat to strike was made, while it was urged that every man who saw fit to endanger the munitions supply by ceasing work should instantly have been transferred to a field of activity where the question of wanton strikes on the part of highly-paid young mechanics would have presented itself to him in a very different aspect.

Although the nature and object of the "embargo" which was the ostensible cause of the strike, have been made abundantly clear, both in the official pronouncement and in the House of Commons, there seems even yet to be a certain amount of misconception on the subject. The embargo consists merely in an instruction by the Ministry of Munitions to certain controlled establishments that they are not to engage further skilled men without special permission of the Ministry. The result of this order, so far as the men already employed in these particular establishments are concerned, is to tend to make their positions even more secure, while as regards others it is merely equivalent to the notice often seen at factory gates: "No hands wanted." It must be clear that the effect of the embargo upon the "privilege" of the skilled workman to obtain employment where he likes, is entirely insignificant. The number of embargoed firms is, and can only be, a very small proportion of the munition works in the country, and the action of the Ministry amounts merely to preventing the creation of spurious vacancies in a few specified firms. No workman is concerned in any way except the very small number who might have filled such vacancies, and even they have the remaining thousands of munition firms to choose from should they desire to change their employment. That an order so relatively unimportant from the workman's point of view should have aroused a deliberate attempt to dislocate the munitions supply by thousands of men in no way affected by it is almost inconceivable, and fully warrants the public indignation which it called forth.

The reason for the embargo being instituted, was to prevent skilled labour being attracted to establishments which already possessed a greater proportion of such labour than could be justified by the nature of their work. There is ample skilled labour in the country to do all the work which requires genuine skill, but there is not such a surplus as to permit of any firm utilising it wastefully. The dilution of skilled labour has long been recognised as a necessity of our present industrial conditions, and the efforts of the Ministry of Munitions to induce firms to employ unskilled and female labour on all work not needing the long training and varied experience of the qualified craftsman have been remarkably successful. Contrary to the expectations of many the unskilled worker trained as a specialist on a single operation, has completely outclassed the skilled mechanic on such repetition work. Hence the effect of dilution, which cannot be considered apart from the concomitant reorganisation of methods, of manufacture, has in general vastly increased the output per employee. The Ministry of Munitions, with all the manufacturing information of the country at its disposal, is in a position to know to what lengths it is practicable to carry dilution on even such exacting works as the production of aero-engines, magnetos or machine guns without detriment, or even with positive advantage to the output per employee. The same department knows equally well that a certain percentage of skilled men must be employed for work which only they can perform. With this knowledge it is not difficult to determine when a firm is flagrantly exceeding the amount of skilled labour to which it is fairly entitled, and it is none the less incumbent on the Ministry to check the abuse, and the embargo on the further engagement of such skilled labour was the method decided upon.

It is not to the credit of any firm, that a check upon its employment of labour should be necessary, but it is creditable to the industry as a whole that so few firms needed official restraint. Unwillingness to adopt such manufacturing methods as would permit of dilution, and a conservative incredulity as to the possibilities of using unskilled labour to advantage are usually the worst charges that can be laid at the door of recalcitrant firms, but occasionally it is to be feared that a certain selfish desire to consider post-war advantages rather than present national necessities must be suspected. Whatever the motive the method of attracting skilled labour from more deserving work, usually consisted in offering exceptional rates of pay or providing facilities for excessively large weekly earnings in respect of a not proportionally large output of work. Such action is always provocative of industrial unrest, and is discountenanced by the more scrupulous firms. It is rendered possible, in a commercial sense, not to say encouraged by the Government itself, as it is one of the evil fruits of "time and line" contracts under which the greater the cost of manufacture, the greater the profits of the firm.

As a result of the strike the Government have promised to institute an inquiry into the working of the embargo. The necessity for the latter has never been in question for a moment, and it almost appears as if the promise of an inquiry was merely a means, provided quite unnecessarily, to enable the strikers to "save their face" and to spare them the humiliation which they have rightly earned. The constitution of the committee of inquiry has just been made public, and very much depends upon its impartiality and wisdom. The point in dispute with the trade unions, namely, whether there should be an embargo or not, is one of those rare questions upon which both the employers and the trade unions may easily find themselves in agreement and both in opposition to the Government. It is abundantly evident that the trade unions object to embargoes, and there is no doubt at all that employers as a whole, dislike Government interference with their methods of conducting business. If, therefore, their representatives on the committee lose sight of the broader national interests in their desire to permit all firms to conduct their shops in their own way, they will be committed to opposition to the principle of the embargo, and therefore become hostile to any method of operating it. There is, we fear, a considerable danger of some such result, and should it occur it would place the Ministry of Munitions in the awkward position of having either to disregard the findings of the committee, or of being forced to withdraw a policy which it has most emphatically stated to be necessary and essential.

Whatever may be the future of the embargo, there is no doubt that the whole dispute has been one of the most humiliating incidents of the war. The conduct of the firms which, in the opinion of the Government made an embargo necessary is no cause for pride. The sequel, resulting in the striking of thousands of munition workers, most of whom are protected from the hardships of military service, for the one and only reason that they should loyally expedite the output of munitions, is a matter for shame. Their grievance, if it can be called a grievance, was trivial beyond words. It is to be hoped that our industry will never again be the scene of such an episode in which the selfish interests of a few were permitted to outweigh their duty to the nation as a whole and particularly to their comrades in the field.

"If ye break faith with us who die
We shall not sleep, though poppies grow in Flanders' fields."

THE NATIONAL PHYSICAL LABORATORY IN 1917–18.

(*Continued from page* 96.)

Metallurgy and Metallurgical Chemistry (Superintendent, Dr. W. Rosenhain, F.R.S.; Messrs. J. Murdock, Guy Barr, S. L. Archbutt, W. Withey, L. Bircumshaw, J. L. Haughton, T. E. Rooney, D. Hanson, E. A. Coad-Pryor, V. H. Stott). *Equipment.*—The most notable feature in the extended foundry is the pit, about 30 ft. by 8 ft., for the gas-heated metal-melting furnaces. The pit is covered by grid plates, separately removable, and the lids of the furnaces are level with the floor; the furnaces are operated by control valves and levers from the floor level, so arranged as not to interfere with the traffic when the furnaces are not in use, and the pit, which is accessible by steps, need not be entered except for cleaning and repairs. The furnaces themselves and the levers do not project from the pit, and the arrangement is both convenient and safe; each furnace can be lifted in the usual way or by the aid of the travelling crane. So far two furnaces have been installed, one of the injector type, of Messrs. Fletcher, Russell and Co., and a natural-draught furnace of the Richmond Gas Stove and Meter Co.; there is also a vertical stove

for preheating iron moulds. The pit is supplied with gas from a 4-in. main and with compressed air at pressures up to 100 lb. per square inch; a 6-in. pipe from a rotary fan further provides air at low pressures up to 10 in. of water. The brick flue, provided with dampers, leads to a special chimney 30 ft. in height; the injector furnace discharges its combustion products into a special flue pipe made in the Laboratory of a carborundum mixture. The very noisy high-pressure injector furnaces are placed in a special room which is ventilated by a fan, behind a double door; these furnaces for temperatures of 1,600 deg. C. and more are built up as required of refractory bricks on a special bench which is arranged with firebrick partitions. The gas and electric furnaces wanted for the researches on glass and refractories are likewise placed in the foundry. They comprise a recuperative gas-fired kiln, the hearth of which measures 18 in. by 33 in., and which can be left unattended for several hours; the control is partly by determining the CO_2 in the flue gases. There is difficulty, however, with the fluctuating pressure of the town gas which calls for the installation of a governor and may necessitate the erection of a small gasholder. Additional arrangements for the supply of compressed air have already been made, Messrs. Reavell putting down a compressor for 65 cub. ft. per minute; this is driven by a three-phase motor at 440 volts, supplied from the stationary three-phase transformer for the furnaces, as a continuous-current cable from the power-house would have been too expensive.

The electric furnaces of the graphite-ring type have proved very successful, and rings of 9 in. internal diameter are now in use. One of these furnaces serves for melting iron and steel for research purposes. Another is arranged as a vertical tube or gradient furnace suitable for thermal curve work; the hottest zone, of 1,600 deg. C. and above, is at the top, and the specimen is pushed into this zone from below. The arrangement obviates the difficulties of finding a suitable suspension wire which will bear the load at the high temperatures, and of exposing the thermocouples to temperatures exceeding those at which measurements are being taken. The mechanical appliances for raising the specimens consist of a ram working in an oil cylinder (below the furnace) which is charged with oil from a tank on the roof of the building. This ram device is also used for introducing crucibles into large furnaces. The further requirements of the department necessitate the addition of a third storey to the Wernher building, as was already stated.

Alloys Research. Aluminium. Steel.—The researches on aluminium alloys have established a number of constitutional models of ternary alloys and have also helped to clear up some questions concerning the various forms in which silicon is found analytically in alloys of aluminium (not all the silicon is converted into SiO_2), and the bearing of these results on the properties of the materials; the anomalous behaviour of some alloys has also been investigated, and to this as to other work the ladies on the staff have contributed their share. As regards magnetic steels, Messrs. Thomas Firth and Sons, of Sheffield, have supplied a set of graded tungsten steels. The magnetic behaviour of these steels showed discrepancies apparently due to their antecedent thermal and mechanical treatment, and it is intended to prepare definite alloys from the pure materials in the electric furnaces of the Laboratory and to examine them magnetically in the ingot and after forging and heat-treatment. Much work has also been done for the Steel Research Committee of the Institution of Automobile Engineers and for the Engineering Standards Committee, and further in advising on gauge-hardening, case-hardening, &c. The issue of standardised steel samples, to serve as standards for chemical analysis, will soon become possible, it is hoped; the Iron and Steel Institute has been urging this standardisation. Substitutes of non-ferrous metals (other than aluminium and its alloys) have also claimed attention.

Optical Glass.—Further promising progress has been made both as regards the preparation of pots and crucibles for refractory materials, some of which do not lend themselves to ordinary casting and shaping, and also as regards the melting and stirring of glass. The one melting furnace which we mentioned last year, was recently put out of action by an explosion which did not cause further damage fortunately.

Metallurgical, General and Aeronautical Chemistry.—The very varied work to be done for Government departments and other bodies now comprises the testing of laboratory glassware of British manufacture. The testing of the purity of hydrogen, and of new methods and apparatus for measuring the permeability and examining other properties of balloon fabrics, and of dopes and varnishes, cellulose acetate, &c., have also fallen to this division.

Physics Department. Electricity (A) *Fundamental Units* (Mr. F. E. Smith, F.R.S., Superintendent, and Mr. H. C. Napier).—The time of this division, to which a staff of women is attached, has almost entirely been occupied with confidential work for the Admiralty, partly connected with radio-telegraphy. The standards of resistance continue in a satisfactory state. Some Weston normal cells have been constructed, and the Laboratory standards of electromotive force have been compared with the standards of Japan, Dr. Yokoyama having brought three normal cells over to Teddington for this purpose. These cells, made in March, 1916, contain a 10 per cent. cadmium amalgam, and the mercuric sulphate was prepared electrolytically, they agreed with the National Physical Laboratory standard cells within 7, 2, 4 parts (average 4) in a million, which is very satisfactory. The agreement of four other cells with a 12·5 per cent. amalgam, which were made by Dr. Shimidzu at Teddington in 1910, according to the instructions of the Laboratory (mercuric sulphate prepared by a chemical process) and which have remained at Teddington since, is not now quite so satisfactory. The preparation of the mercuric sulphate and the composition of the amalgam gave rise to long-continued international researches before the war.

Magnetic Disturbances of the Laboratory.—Before electric propulsion was introduced on the London and South-Western Railway, an understanding was arrived at in 1913 between the company and the Laboratory as to the magnetic disturbances which the running of the trains might cause at the Laboratory. The Laboratory was already disturbed by the electric tram service along the main street of Teddington, and the railway company agreed not to exceed those disturbances by more than 20 per cent. The aperiodic qualities of his magnetographs in the magnetograph hut of the Laboratory allow Mr. Smith to determine those disturbances quantitatively with comparative ease. Occasional 24 hours' records taken during the past year further show that the horizontal magnetic field at the Laboratory is increased by more than the 20 per cent. stipulated; the matter was referred by the Office of Works to arbitration, and the award of the arbitrator was given to this effect in December, 1917. The magnetic hut is used for experimental purposes and compass testing, &c.; the magnetograph records are hence not available for general magnetic observations.

B. *General Electric Measurements. Inductometers, Solenoids, Magnetic Tests.* (Messrs. A. Campbell and D. W. Dye).—The ordinary testing work, apart from official work, has doubled since 1915. The new standard mutual inductometer for a maximum of 1 millihenry (starting from a microhenry), is wanted particularly for wavemeter coils; the instrument is similar in design to the larger 10 millihenry* inductometer previously made in the Laboratory. The coils are mounted on white marble supports. Two accurately-wound search coils were submitted for most accurate testing, and in this connection an investigation was made of the uniformity of magnetic fields due to solenoids. In the usual examination of search coils the product: number of turns times area, is determined, and for conducting the checking test the coil is placed inside a solenoid or near some other primary coil of such a kind that the magnetic field produced at the search coil by a known primary current can easily be calculated; the mutual inductance of the combination against a standard is then determined. The solenoid should be as uniform as possible, especially when the axial length of the search coil is not relatively small, but uniform winding is very difficult to secure. Our readers may remember the great difficulties which Mr. F. E. Smith and the Metrology Department experienced in making the coils for the Lorenz apparatus for the absolute determination of the ohm; in this apparatus the wires are placed in grooves turned in marble cylinders. For ordinary measurements, especially with suspended coils, marble tubes would be unsuitable, of course. Investigating the uniformity of solenoids wound on long smooth tubes in 1911, Gehrcke and Wogau observed considerable discrepancies, and Mr. Campbell corroborates them. Moving a search coil to various positions along the axis, he found variations of 1 per cent. and 2 per cent. from the mean, after allowing for the finite length of the solenoid. The standard search coil was a single-layer coil of enamelled wire, very carefully wound on a marble cylinder of 3 cm. diameter, and the values of the measured dimensions and of the inductance determination agreed within one part in 1,000. To obtain higher accuracy would require much greater elaboration in the design of the solenoid, and for use with alternating currents particularly it is difficult to find a suitable tube material.

The magnetic work has been varied. The reliability of various methods is under investigation, and a number of materials have been tested, non-magnetic steels as well as ordinary steels, the magnetic change points of which have to be determined, and low-silicon iron; in this latter case the object is to find the hysteresis loss and permeability at telephonic frequencies due to the superposition of direct-current magnetisation. The testing of horse-shoe magnets is a very difficult matter because the bent and chilled bar is not uniform in material and cross-section, a hole is pierced in each limb to fix the pole-piece, and the coils to be slipped over the limbs should fit the curved surfaces as closely as possible and must be made of stout copper wire to take currents of 20 amperes without getting hot. Sets of narrow flat coils (on glass), jointed together in series, weighing up to 12 lb., have been found useful for this work. For some purposes alternating current measurements have to be made at 10 periods per second, and a simple arrangement has been set up to serve as a steady source of such currents. It consists of a long, electrically-excited tuning fork; to the end of the one limb is fixed a horizontal piece of cardboard on which a coil is mounted, and this coil is by the fork moved into and out of the pole gap of a permanent magnet; a very sensitive vibration galvanometer for this frequency has been constructed. The apparatus now under construction for the determination of effective resistance in radio-telegraphic apparatus concern the power-losses at the high radio-frequencies; the experimental currents will be generated by a secondary battery of 400 volts combined with large valves, and the determination will be calorimetric.

Electrotechnics. A. *General Work. Height Finders. Photometry* (Messrs. C. C. Paterson, A. Kinnes, J. W. T. Walsh, Dr. Norman Campbell).—Mr. Rayner being still absent on other duties and Mr. Dudding having been transferred to the Metrology Department, the heavy official investigation work had to be carried on with a depleted staff. The equipment has hardly been increased under these conditions, but the acquisition of most of the apparatus from the laboratory of the late Mr. Duddell is highly valued, the apparatus being so perfect. A great deal of further work has been done with the Paterson-Walsh height finder, and assistance with these instruments has been given both in this country and in France. The investigation of insulating materials has special reference to magneto distributors, *i.e.*, attachments to magneto machines by means of which the high-potential currents—from large-size tungsten-lamp rectifiers—are distributed to the separate igniters; the insulation of these distributors has to be very durable, since brushes rub over the contact pieces embedded in the insulation. Ebonite and special insulating materials have been tested for mechanical and electrical properties including tendency to carbonise with sparking, and mica condensers have

* 1 henry (secohm or quadrant) is 10^9 cm.

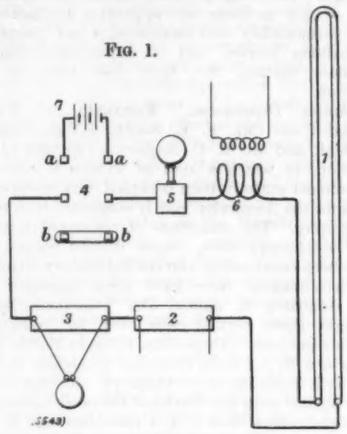
been examined to test the effect of traces of air in the mica.

At the request of the Engineering Standards Committee measurements have been made of the temperature in ventilated and unventilated sockets of Goliath lamps and other lamps used in lanterns of the open and enclosed types. There is considerable heating in the sockets owing to the conduction of heat from the bulbs, and it was found that the temperature in the leading-in cables might rise to 140 deg. C. and that the existing arrangements for socket ventilation did not afford much improvement. Satisfactory methods had also to be devised for the photometry of gas-filled lamps. The ordinary step-by-step method is slow, particularly when the lamp cannot be rotated, and for most purposes a knowledge of the average candle power is all that is wanted. This can be done with the aid of the cubical integrating photometer box suggested by Dr. Sumpner which we mentioned last year. It is a room rather than a box, and should be spherical instead of cubical; the internal walls of the room are painted dull white; the lamp under test, which may be a searchlight, is mounted or suspended in the box, and the beam passes out through a window in one of the walls, outside of which the photometer bench is mounted. In order to be able to examine the crater of an arc separately from the arc, the rays from the crater are by mirrors reflected through a second window, so as to fall outside on the diaphragm disc of a second bench; this disc has a hole in the centre and the light spot is, by a lens, magnified to cover the photometer disc. Light filters and standard vacuum lamps running at normal temperature are used in the measurements; but Mr. Paterson is not satisfied with the arrangements, and these will be perfected as soon as conditions permit. Searchlight carbons are also under examination.

As regards the decay of luminous paints the observations mentioned last year, continue, and the work connected with these compounds has increased owing to their extended use; gunsights are now sent for regular examination. Various forms of self-luminous graticules for gun sights have been studied for the Munitions Inventions Department, and several such forms have been made at the Laboratory; the difficulty is that the line should be both sufficiently luminous for good visibility and narrow for precision in sighting.

B. *Continuous Current. Resistance. Buried Cables.* (Messrs. S. W. Melsom and H. C. Booth, Miss V. Cockburn.)—Apart from routine work and special investigations for the Admiralty and the Aeronautical and other departments, the chief investigation has been on the heating of buried cables. This work is in a measure completed, and an interim report has been presented to the Institution of Electrical Engineers, but not yet published. Meanwhile it has been decided to include in the inquiry a determination of the dielectric losses in the cables, which will involve further laborious work, but will make the report still more valuable to electrical engineers who are ready to bury cables as soon as they are more reassured as to the risks they may run. We described the method in last year's report.* The cables, so far all paper insulated, in sections of 100 ft. length, are first laid on the floor of the Laboratory to determine their constants. They are then placed in the conduit built for the tests, which extends between two huts with concrete foundations serving as small laboratories. The cables are laid direct in the ground, or solid in bitumen, or drawn into a six-way duct of stoneware. The laid cables are heated by alternating currents, and the increase in the resistance of the conductors is measured by means of a Kelvin double bridge. To make the use of galvanometers possible, a small continuous current of about 20 amperes from a battery is superimposed upon the heavy alternating currents of 500 amperes, the accumulators being put in series with the secondary winding of the transformer and with the cable by a double-pole change-over switch. Fig. 1 explains the general arrangement; 1 indicates the cable, 2 a standard shunt, 3 the two-wire ampere-meter and shunt, 4 the double-pole switch, 5 the current transformer and precision current meter, 6 the transformer, and 7 the battery. While the observations are being made the whole alternating current is flowing through the battery, and the double bridge and galvanometers are carrying a comparatively large alternating current in addition to the small continuous current to which they respond. Resistance measurements are made on the inner and the outer conductor of a cable (if concentric) and on the lead sheathing, the latter measurement indicating the temperature of the outer portion of the cable.

Fig. 1.



The mean resistance value of 230 samples of the copper conductors in the cables was 0·1541 ohm per meter-gramme at 20 deg. C., the temperature coefficient being 0·00390 at 20 deg.; 31 samples of lead sheeting gave a mean resistance of 2·443 ohms per metre-gramme and an average temperature co-efficient of 0·00385; the latter figure varied between 0·00404 and 0·00373. In general, the temperature rise of a cable drawn into the stoneware duct was twice that of a similar cable armoured and laid direct in the ground; the cables laid solid in bitumen occupied an intermediate position. The report will give particulars of these figures and also of the time periods in which the cables attain their maximum temperatures; the effect of the ends, and the temperature gradients in the cable and in the duct (a point to which we referred last year) are also discussed in the report. For the further tests a special motor-generator set is under construction, the set being wanted in general for heavy continuous-current work. The set consists of two continuous-current generators, each fitted with two commutators, each to carry 1,250 amperes at 6 volts; by means of a series-paralleling boards, currents of 1,250 amperes at 24 volts and of 5,000 amperes at 6 volts will be available; the generators are driven by a three-phase motor for 3,000 volts from the town supply.

Assistance has also been given to the Aerodynamics division in experiments on engine cooling. Attempts to detect defects in bridge girders by electric and magnetic methods have proved fruitless; the methods did not indicate incipient cracking before mechanical weakness had already set in.

Heat. A. *High Temperature and General Work. Pyrometry.* (Dr. Ezer Griffiths, Mr. E. H. Schofield.).—Dr. Harker (Ministry of Munitions) and Captain Blackie (on active service) being still absent, the large volume of routine work has left little time for high-temperature research. A room is being equipped for optical-pyrometry work; special tungsten arcs (buttons) have been prepared by the Edison-Swan Company for the division to serve as comparison source in calibrating pyrometers over the apparent range 900 deg. to 2,400 deg. C., and improved graphical methods have been devised for computing the results of observations with optical and with total radiation pyrometers. Diaphragms of various apertures have been fitted to three standard total-radiation pyrometers so as to obtain a series of overlapping scales, and further progress has been made with standardising directly against the melting-point of gold or palladium, as we described last year*; the observer sights upon a diaphragm in a furnace (giving black-body radiation) across the face of which a wire of one of these metals is stretched, and raises the furnace temperature until the circuit is interrupted by the melting of the wire. Total-radiation pyrometers have been calibrated at 1,550 deg. C. in this way, and it is also confirmed that the freezing-point of the nickel-graphite eutectic, 1,330 deg. C., may be utilised as a fixed point for the calibration of thermocouples. For accurate work with platinum thermocouples at high temperatures it is most essential to make sure that the wires are not contaminated by the vapours of other metals and furnace gases. Recalibration of a suspected thermocouple does not suffice to ascertain whether the "furnace end" is contaminated or not, should the affected portion be within the uniformly-heated region of the furnace. It is hence desirable to test the wire in short sections, and Messrs. Griffiths and Schofield effect this with the aid of a clever little device. It consists of two copper wires, fixed parallel to one another, a small distance apart, the one kept hot, the other cold,

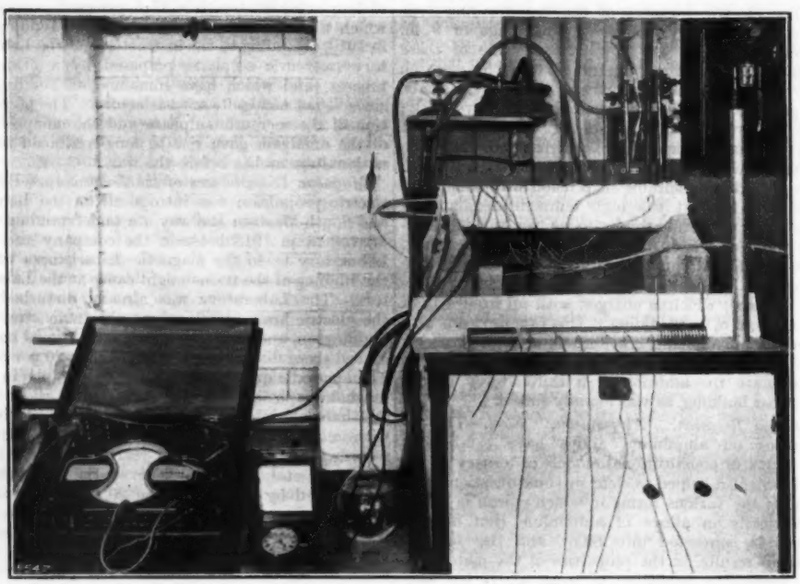


Fig. 2.

*Engineering, June 29, 1917, page 624.

* See Engineering, July 13, 1917, page 33.

across which the section of the wire under test is laid; the copper wires are joined to a potentiometer, and the thermo-electric force is measured. Another section of the test wire is then brought into contact with the copper wires, which it crosses at right angles, and the measurement is repeated. The wire under test is carried in a frame which is moved by means of a rack and pinion, so that the observer can traverse the wire which, during the measurement, is pressed into good contact with the copper wires by the aid of a pad and a weighted lever. Each copper wire is longitudinally soldered to the top of a small copper tube; steam passes through the one tube, and cold water through the other.

Pyrometer Tubes. Thermal Conductivity. Electric Hot Plates and Cold Storage.—When examining pyrometer sheaths of British manufacture for softening point and porosity at high temperatures, the tubular sheath is fixed horizontally with its end projecting as a cantilever into a furnace so that the conditions are the same as when the tube serves as sheath for a pyrometer; the temperature of the furnace is slowly raised and is maintained steady for hours, until the tube bends under its own weight. To determine the porosity the tube, inserted into the furnace with its closed end, is exhausted to a few millimetres of mercury; the pump is then shut off, and the rise of pressure in the tube is watched. In this porosity test some porcelains even unglased came out remarkably well, the walls of the tube collapsing before any leakage of gas into the tube became noticeable; tubes of fireclay and of shrunk alumina on the other hand frequently showed a return to atmospheric pressure within 10 seconds. The thermal conductivity tests were made on aluminium and its alloys for the Advisory Committee on Aeronautics. The light aluminium alloys are valued as material for the construction of cylinders and pistons of aircraft engines also on account of their high thermal conductivity, as to which there were no reliable data, however, especially not at the temperatures ranging up to 300 to be met with in service. The research, which was extended to other metals, naturally started from pure aluminium, particularly also because the determinations of the thermal conductivity of aluminium, made in relatively early days, showed certain anomalies probably due to the impurity of the metal. The determinations were made by an absolute method, the heat transmitted to a cylindrical rod being measured by a flow calorimeter, while the temperatures along the rod were determined by means of a series of thermo-junctions. The photograph, Fig. 2, illustrates the general arrangement. The rod, about 1½ in. in diameter, 18 in. long, lying on the table in front, is ready for insertion in the apparatus (further behind) which is shown fully lagged and connected with the auxiliary devices, the cold-junction box and the potentiometer, for taking observations. The one end of the rod is heated by a wire coil; the other end is cooled by a water coil; the quantity of electric heat put in is equal to the sum of the heat carried away by the water and of the heat lost, and the temperature gradient along the rod is determined by the six thermocouples shown in position in the photograph. The novelty about these latter measurements is that Dr. Griffiths does not insert the two wires forming a couple into the same hole; he drills two small holes diametrically opposite each other into the bar and fixes one wire in each hole by driving in a taper pin; the hot junction of the couple is thus formed by the cross-section of the bar. Iron-constantan couples were used, and the method admitted also of checking the accuracy of the correction for the heat lost through the lagging of the bar. It was found, as was expected, that pure aluminium conducts heat like other pure metals do, and that the thermal treatment of the various alloys has a considerable influence on their subsequent thermal properties. A summary of the results obtained has been published and circulated by the Air Ministry to the manufacturing firms concerned.

In collaboration with the Heating and Cooking Panel of the Engineering Standards Committee, efficiency tests have been developed of electrical hot plates and cooking stoves. These apparatus, roughly of the radiation and of the direct-contact types, differ largely in design and as much probably in efficiency. Another investigation, taken up on the instigation of the Food Department, is that of testing thermal insulation like cork, charcoal, &c., under cold storage conditions. An ammonia refrigerator has been installed in a basement of Bushy House, and brine is circulated through flat coils of lead piping (square in section), so as to supply cooling surfaces several feet in diameter; mats of the insulator to be tested are placed over or near this coil and tested as in the previous work on heat insulations.

(To be continued.)

NOTES.

British Scientific Products Exhibition.

The British Science Guild, with the assent of the Ministry of Munitions and the approval of the Board of Trade, is arranging for an exhibition to be held at King's College, Strand, London, W.C., for four weeks, from August 12 to September 7. This is to be a display of products and appliances of scientific and industrial interest which, prior to the war, were obtained chiefly from enemy countries but are now produced in the United Kingdom. Other classes of products to be shown are those in the manufacture of which we excelled in this country even before the war and exported to enemy countries, and those we have developed on an extensive scale since the date when Germany started the war. In point of fact, the exhibition is destined to prove that by the combination of science and industry we have accomplished nearly as much in the four years of war as the Germans did in the preceding forty years. One of the main effects of the exhibition will be to make clear to all the necessity of scientific research with respect to the application of its results in the arts and industries. It will cover a very large variety of articles, including synthetic dyes; pigments; heavy chemicals; pharmaceutical preparations; pure chemicals; pyrometers; electrical and electromagnetic appliances, with the special materials used in their manufacture; optical apparatus of all kinds; glass, quartz, refractories and porcelain for scientific and industrial purposes; dividing machines; drawing, mathematical and surveying instruments, &c. Competent attendants will be appointed by the committee to give such explanation of the character and purpose of the exhibits as occasion may demand. Lectures and addresses are to be delivered dealing with important departments and features of the exhibition, the special aim of these lectures and addresses being to direct public attention to the vital necessity of developing the scientific industries and of applying the results obtained in scientific research to everyday practice. We feel confident that the exhibition will prove a success in that it will lead the public to see that our scientific men and our manufacturers can surpass German effort when conditions of development are favourable. We hope that all sections of the British community will contribute together to maintain for the future the independent position we have now achieved in the production of articles of prime importance not only for the home market but also for foreign markets, hitherto manufactured in or imported from enemy countries. The address of the British Science Guild is 82, Victoria-street, S.W. 1, Mr. F. S. Spiers being the organising secretary for the exhibition.

The Chemistry and Metallography of Aluminium.

Two of the papers brought before the meeting of the Faraday Society, held on July 23 last, dealt with aluminium. The first, by Mr. John G. Rodin, F.I.C., "Contributions to the Chemistry of Aluminium and its Alloys," was largely analytical in character. As chemist of Messrs. H. I. Raphael's Refinery, Mr. Rhodin has had to analyse tons of aluminium scrap and swarf (turnings, &c.), and as these alloys consist practically of aluminium with low or high percentages of zinc and copper, he successfully attempted to sort the metal by means of a gravity test. He observed that alloys containing from 4 per cent. up to 60 per cent. of these other two metals showed densities increasing from 2·767 up to 3·519. As the aluminium percentage decreased, the rate of this rise in density was first rapid, diminishing afterwards; but Mr. Rhodin's data were hardly sufficient to support the inflection-point in his density curve at about 76 per cent. Al to which he drew attention. As regards the chemical analysis of Al and its alloys he made the important statement that he had found a direct method of determining the metallic aluminium. So far there is no practical direct method known, and that is all the more regrettable since the indirect methods count all that is not copper, zinc, silicon, &c., in the alloys as metallic aluminium, whilst a good deal of the assumed aluminium may really be present as oxide; there is always plenty of oxide in scrap in particular, but the determination of its percentage is very difficult. Mr. Rhodin stated that he can dissolve all the metallic aluminium in an alloy by caustic soda of 10 per cent.; what remains insoluble consists of alumina and the other metals; the residue is dissolved in nitric acid, and the solution is further analysed in the usual way. The residue might still contain some metallic aluminium, and oxide or basic carbonate might be formed during the process of dissolution; but he had not overlooked that. Such a method would, as Dr. Rosenhain pointed out, be of very great value, but he had his doubts; while Dr. Seligman, Dr. Gwyer and others criticised the statements as inacceptable. Mr. Rhodin further considers that there are two aluminium oxides, a suboxide Al_2O, and the oxide Al_3O_4; the latter he believes to be produced on burning the metal in air, and to form a solid solution with the metal. Mr. Rhodin claimed to have some evidence of having isolated Al_3O_4; the oxide is generally given the formula Al_2O_3. It cannot be said, however, that his analyses were very convincing; they were all brought up to the correct total 100·0 by ascribing the difference to copper or zinc, &c., which should have been determined separately. Thus there is no check on his analyses. On the other hand, Mr. Gertin and others pointed out that Mr. Rhodin's many analyses and other tests were concordant and had never been questioned by the interested parties. It is to be hoped that the matter will further be investigated. Mr. Rhodin is also engaged in specific heat tests which he performs with the aid of a calorimeter, the copper vessel of which is lowered into a vacuum vessel quite 2 ft. in height. Some interesting remarks on aluminium were made during the discussion. Dr. Rosenhain said that a certain percentage of iron in the aluminium, ½ per cent. and even 2 per cent., was not at all a disadvantage, and Mr. C. Vautin showed an experiment with a blackish aluminium powder, which contained about 70 per cent. of metallic aluminium. When a small heap of this powder was placed on an iron tray, and lighted with an ordinary match—the granulated aluminium thermit of Goldschmidt requires lighting with a "cherry" of some peroxide—it first glowed like charcoal, and then began to burn with an intense glow, but very quietly. Mr. Vautin suggested that the first glow probably produced the suboxide Al_2O of Mr. Rhodin which subsequently burned to oxide or peroxide. So far the first paper. The second paper was by Mr. Robert J. Anderson, of Cleveland, Ohio, on the "Metallography of Aluminium, recrystallisation and grain growth, the result of deformation in the cold prior to annealing," and gave further proof* that aluminium resembles other metals as regards annealing.

German Industrial Boards.—The increasing extent of overlapping and intermingling between German commercial, and financial undertakings has been further illustrated by some particulars just published. Herr Hugo Stinnes, who has been very much to the fore, is now a member of 45 boards, an increase of five during last year, and Herr Walther Rathenau, the president of the A.E.G., is now on 40 boards, an increase of one during 1917. There are, however, men with even larger totals to their credit; thus Dr. Louis Hagen, Cologne, is on no less than 57 boards. Herr Karl Fürstenberg (Berliner Handelsgesellschaft) on 55; Dr. Georg Solmssen (Disconto Gesellschaft) on 52; Dr. von Schwabach (of the Bleichroder banking firm) on 48. Herr Oscar Schlitter (Director of the Deutsche Bank) is on 38; and Herr Kommerzienrath Peter Klöckner, Duisburg, is on 30.

* See Engineering, April 12, 1918, page 412 as to a paper on "Annealing of Aluminium," communicated by Mr. Anderson to the Institute of Metals.

LITERATURE.

* *Organic Compounds of Arsenic and Antimony.* By Gilbert T. Morgan, D.Sc., F.I.C., F.R.S., Professor of Applied Chemistry, City and Guilds Technical College, Finsbury. London: Longmans, Green and Co. [Price, 16s. net, bound.]

The remarkable therapeutical potencies of organic arsenical compounds have so generally been discussed of late, that the public may ascribe an essentially physiological importance to the study of such compounds. To the chemist, the primary importance of this study lies in its wider, theoretical bearing. In some of these compounds arsenic replaces nitrogen. In the reactions of inorganic chemistry the two elements display close analogies. The living organism does not contain arsenical compounds, but organic arsenical compounds have been prepared, and they suggest novel analogy aspects. A slight deviation may help to explain the nature of the problems.

The chief constituents of organic substances are carbon C, hydrogen H, oxygen O, nitrogen N. The hydrocarbons, gases like methane, the oils of petroleum, &c., consist merely of C and H; the carbohydrates, sugar, cellulose, &c., contain nothing but C, H, O. Many of these and other compounds are certainly organic in the sense that they are produced in plants and animals, though they can also be prepared from their elements. Nitrogen seems to be indispensable to the living system in a special sense. While the plant is able to build up albumenoids from nitrogen compounds, such as salts of ammonia, which certainly are of inorganic origin, the animal system does not appear to be able to exist and to build up the all-important proteins of the blood and tissues unless fed on nitrogen of organic origin. When Wöhler succeeded, in 1828, in preparing urea, a secretion of the animal system, by starting from ammonium cyanate, a furnace product, the wall separating organic from inorganic chemistry seemed to be broken down. Other organic syntheses followed, first at a very slow rate, later in amazing numbers and variety. The terms organic and inorganic chemistry were retained merely for the more convenient classification of the multitudes of carbon compounds, and as the foundations of constitutional chemistry became more firmly established, the chemist felt tempted to investigate whether he could, in strictly organic compounds, replace one element by another closely related to it chemically; for instance, carbon by silicon, and nitrogen by arsenic. Nitrogen belongs to a group of elements which further comprises phosphorus (a non-metal), arsenic and antimony (metalloids), bismuth (a metal). In their physical properties these elements and their compounds differ widely; in their reactions, they follow analogous lines. The first discovery of organic arsenical compounds was accidental; later, the chemist began to study them for their own sake, and for the purpose of widening his theoretical horizon, and also with the object of investigating the effects of such compounds upon the human system. The former study should obviously precede the latter. But science advances in different directions, sometimes by leaps into the dark, and we are so ignorant about what is really going on in our system, that any promising line of research is eagerly taken up. On the whole, it would be better, we think, if physiological experiment followed the thorough chemical and physical investigation of a new compound, and did not precede it, as it frequently does still; that would prevent much serious blundering and a good deal of suffering of animals. Unfortunately, the physiological and the chemical studies are largely in different hands, and neither the chemist nor the physiologist pays sufficient heed to the physical side of the problems which may supply the clue to their solutions. Schools of physiological chemists, men and women devoted to their science, have, however, grown up of late, and books like Professor Morgan's "Organic Compounds of Arsenic and Antimony" will facilitate the work of these investigators.

Professor Morgan's historical sketch of his section of science is characteristically interesting; opportunities seem so often to have been missed. Nearly 200 years ago the French chemist Hellot was informed that a German artist had extracted, by means of *aqua fortis*, a sympathetic ink from the mineral cobolt of the Schnecberg district in Silesia. The mineral was probably Glanzcobalt or smaltite, an arsenide of cobalt, nickel and iron, then already utilised as a raw material for making smalte (the blue ceramic pigment) and white arsenic. Twenty years later, in 1760, a military apothecary of Paris, L. Claude Cadet, still in search of a sympathetic ink, obtained from cobolt a liquid, the vapours of which had an intolerable stench and caught fire on exposure to air. The matter excited attention, but the essential constituent of Cadet's fuming liquid, the heavy oil cacodyl ($As(CH_3)_2$), was only isolated and studied by Bunsen in 1837, and its constitution further investigated by E. Frankland in 1849. Frankland's intervention, Professor Morgan remarks, did not inspire many other English chemists to study the organic derivatives of arsenic, and the British contribution to this section of organic chemistry is of very modest dimensions. Extending Bunsen's work, Baeyer, in 1858, prepared the new cacodyl or arrhenal, which Gautier first applied in the treatment of malaria in 1902. Meanwhile, Löwig and Schweitzer, of Zurich, had synthesised the first organic derivative of antimony in 1850; Béchamp had prepared the first aromatic arsenical in 1860, which Schild and collaborators, in 1902, introduced into therapeutics under the name of atoxyl—the name indicates the comparatively non-poisonous character of the drug—and A. Michaelis, with La Coste and others, at Karlsruhe, and later at Rostock, early in the seventies, had entered upon the systematic study of aromatic derivatives of phosphorus, arsenic and antimony. Still in the same year, 1902—Dr. Morgan does not draw attention to the recurrence—Thomas and Breinl, of the Liverpool School of Tropical Medicine, applied atoxyl with success in the treatment of sleeping sickness.

These researches were the forerunners of Ehrlich's great work. Atoxyl, whose real constitution was only disclosed by Ehrlich—it is sodium arsanilate, $NH_2 . C_6H_4 . AsO(OH) . ONa$—and its homologues are derivatives of quinquevalent arsenic, in which the principal valencies of that element are fully saturated. Guided by Bunsen's researches, Ehrlich recognised that aromatic compounds of tervalent arsenic are much more efficacious than those of quinquevalent arsenic in combating diseases like the sleeping sickness, relapsing fever and syphilis, attributed, not to bacteria, but to blood parasites of the protozoa type. In the case of the tse-tse fly disease and of the sleeping sickness, the parasites are tripanosomes, worm-like organisms, swimming about in the blood, whilst the much smaller parasites of some other cattle diseases actually live in the red blood corpuscles. After many laborious experiments, Ehrlich, in 1909, found the 606th compound he investigated to be a strong syphilis specific, which was called salvarsan: it consists of two benzene rings doubly linked by the arsenic atoms in them:

$$C_6H_3 . NH_2 . OH . As = As . OH . NH_2 . C_6H_3.$$

The drug used is the dihydrochloride of this compound; in the application, the acid compound is neutralised with caustic soda, and injected into the veins. This application requires great care, and Ehrlich, in 1911, brought out neosalvarsan, the methylene sulphonate of salvarsan, which is neutral and soluble in water. At the Medical Congress, held in London in 1913, he then announced that these aromatic arsenicals could be coupled with salts of the heavy metals (platinum, gold, silver, copper), thus reinforcing their germicidal action, whilst lessening the toxic effect on the patient. There is, of course, great danger in the use of all such remedies, and unexpected serious complications have sometimes arisen. Arsenical proteins, in which the characteristic arsenic reactions are masked, have also been prepared.

Ehrlich started his researches together with Bertheim, Benda, Karrer and other collaborators, in the Georg Speyer Hospital, at Frankfurt, and continued them in the laboratories of the Hoechst Farbwerke, vormals Meister, Lucius und Brüning; most of the patents are in the name of this firm. It was only in quite recent years that the firm of Poulenc Frères took up the manufacture of these remedies in France, and Messrs. Burroughs, Wellcome and Co., long famous in therapeutical chemistry in this country; Messrs. May and Baker are connected with Poulenc Frères. To these firms, and to their distinguished chemists, to Dr. W. H. Martindale, his collaborator in this field of research, and to Mr. E. Scholl, Professor Morgan expresses his particular indebtedness for assistance in preparing this publication. In France, Mouneyrat (the inventor of galyl) and Danysz (luargol) have lately been successful in the coupling reactions to which we referred. In America, Palmer and Dehn have, since 1894, developed new methods of preparing arsines, and the hexaminoarsino benzenes of Boehringer and Soehne are now receiving much attention because they form stable salts with soluble bicarbonates. Of English workers in this field not yet referred to, Drs. Plimmer and Pyman are frequently mentioned in the volume.

All these researches are very ably reviewed by Professor Morgan in his octavo volume of 376 pages. The compounds are grouped under the headings, cacodyl, aliphatic arsenicals and antimonials, aromatic arsenicals, atoxyl and the Béchamp reaction, salvarsan, &c. It is a scholarly work, practically unique. The previous compilations, by Bertheim, by Nierenstein and by Dr. Morgan himself, did not cover the whole ground, and it is noteworthy in these days that Dr. Morgan has brought up the bibliography (10 pages) to the end of 1917. He writes for the chemist, of course; the physiological actions of the compounds are duly pointed out, but he could not deal with the physiological investigations, and the two excellent indexes (15 pages of names and subjects) do not contain such entries as malaria. With the possible exception of diethylarsine, which is produced by the growth of moulds on carpets and wall-papers containing arsenical pigments, all the compounds in question are synthetic laboratory products. Nature does not supply them any more than it substitutes silicon for carbon in plants and animals, a subject on which we recently commented.* The efficacy of the remedies may partly be due to their being altogether foreign to the human system, and physiological considerations will call forth new efforts. But the chemist requires no incentive for the study of organic arsenicals.

BOOKS RECEIVED.

Heating and Ventilation. By John R. Allen and J. H. Walker. London: Hill Publishing Company, Limited. [Price 15*s.* net.]

Colour in Relation to Chemical Constitution. By E. R. Watson, M.A.(Cantab.), D.Sc.(Lond.). London: Longmans, Green and Co. [Price 12*s.* 6*d.* net.]

Electric Motors and Control Systems; A Treatise on Electric Traction Motors and their Control. By A. T. Dover. London: Sir Isaac Pitman and Sons, Limited. [Price 16*s.* net.]

Transactions of the Institution of Water Engineers. Vol. XXII, 1917. Edited by Percy Griffith, M.Inst.C.E., F.G.S., Secretary. London: St. Bride's Press, Limited.

The Journal of the Institute of Metals. Vol. XIX. Edited by G. Shaw Scott, M.Sc., Secretary. London: Published by the Institute. [Price 21*s.* net.]

The Flying Book. 1918 Edition. Edited by W. L. Wade. London: Longmans, Green and Co.; Bournemouth: The Aviation World Publishing Company, Limited. [Price 5*s.* net.]

Wealth from Waste; Elimination of Waste a World's Problem. By Henry J. Spooner, C.E., F.G.S., M.Inst.C.E. With a foreword by the Right Hon. Lord Leverhulme. London: George Routledge and Sons, Limited. [Price 7*s.* 6*d.* net.]

From War to Work. By Samuel Turner. London: Nisbet and Co., Limited. [Price 1*s.* 6*d.*]

The Zinc Industry. By Ernest A. Smith, Assoc.R.S.M. London: Longmans, Green and Co. [Price 10*s.* 6*d.* net.]

Elementary Engineering Papers for Naval Cadetships (Special Entry) for the Years 1913–17. Edited by R. M. Milne, M.A. London: Macmillan and Co., Limited. [Price 1*s.* 3*d.* net.]

Special Reports on the Mineral Resources of Great Britain. Vol. VI. *Refractory Materials: Ganister and Silica-Rock.—Sand for Open-Hearth Steel Furnaces.—Dolomite.* London: E. Stanford, Limited. [Price 7*s.* 6*d.* net.]

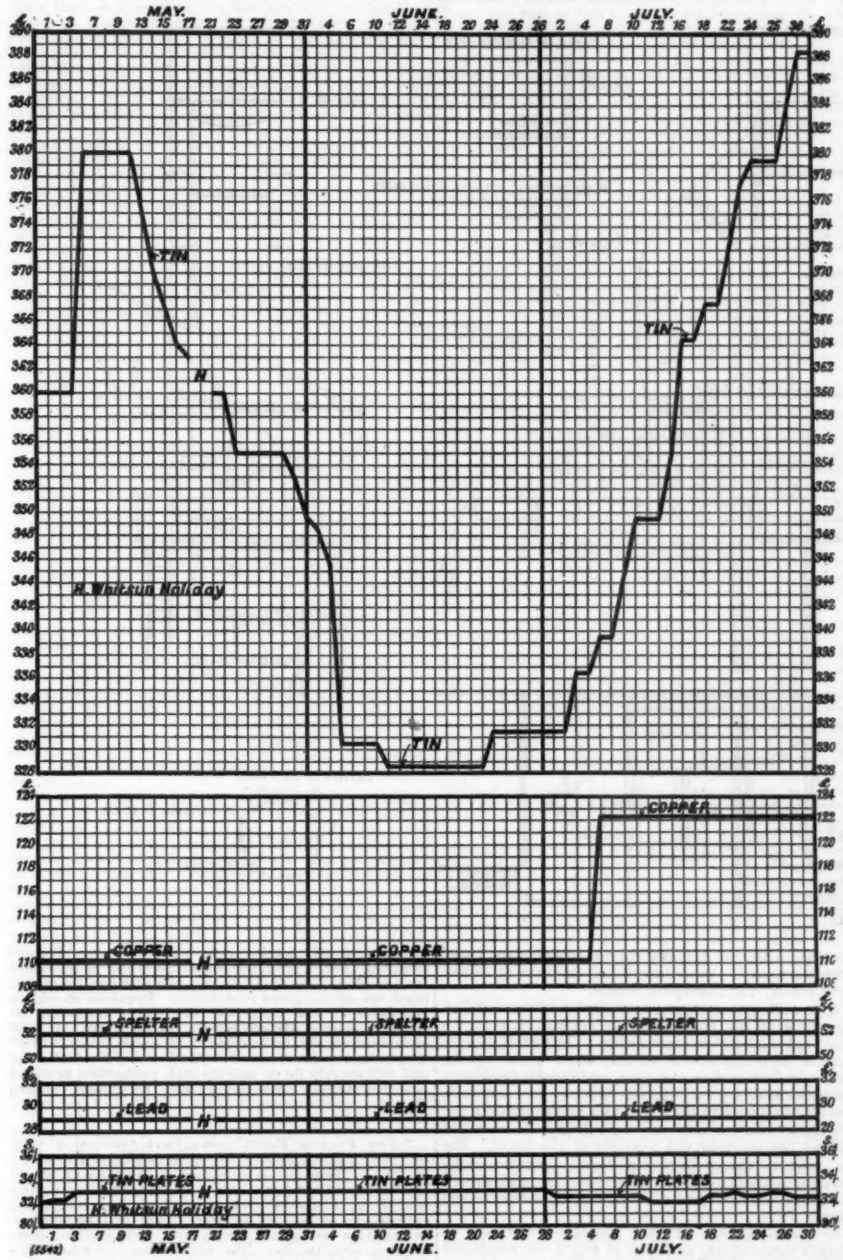
Wireless Telegraphy and Telephony. A Handbook of Formulæ, Data and Information. By W. H. Eccles, D.Sc., A.R.C.S., M.I.E.E. Second Edition, revised and enlarged. London: Benn Brothers, Limited. [Price 22*s.* net.]

High Explosives; A Practical Treatise. By Captain E. de W. S. Colver, D.Met., F.C.S., A.I.A.E. London: Crosby Lockwood and Son. [Price 3*l.* 3*s.* net.]

* See Engineering, May 17, 1918, p. 552.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagram above the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. The prices are per ton. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7, 1916, the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig iron was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. These quotations are still in force. (For official regulations see page 45, vol. cii.)

BRITISH FUEL OIL.—The question of the production of fuel oil from home sources has been investigated by a committee appointed by the Minister of Munitions, and under the chairmanship of the Marquess of Crewe. The report, just issued, states that the best method is the carbonisation of cannel coal in existing vertical retorts at gas works, although no very largely increased quantity of oil can be obtained from this source during the war owing to difficulties of labour, coal transport, &c. The Petroleum Research Department had recommended the erection of batteries of a form of low temperature retort for the carbonisation of cannel coal, but an experimental investigation of low temperature processes by the Ministry has proved that the suggestion was impracticable on the grounds of expense, shortage of labour, time involved, and the fact that the mineral is not available in the quantities which the first investigations indicated. The committee indicates other sources of supply as available in the future. These sources include boring for oil in Great Britain, the further development of the Scottish shale oil industry, and the increased carbonisation of raw coal. In this latter connection the report states that some 1,250,000 tons of fuel oil might be obtained from every 20,000,000 tons of coal carbonised.

IMPERIAL MINERAL RESOURCES BUREAU.

At the Imperial War Conference last year it was agreed that it was desirable to take steps to set up an Imperial Mineral Resources Bureau, which should be charged with the duties of collecting information from the appropriate departments of the Governments concerned and from other sources, regarding the mineral resources and metal requirements of the Empire; and of advising from time to time what action, if any, may appear to be desirable to enable such resources to be developed and made available to meet the metal requirements of the Empire. Accordingly, a special committee under the chairmanship of Sir Jas. Stevenson, Bart., was appointed to examine this proposal and to report upon the duties and administrative responsibilities of the proposed bureau. The committee defined the duties of the bureau as follows:—

(*a*) To collect, co-ordinate and disseminate information as to resources, production, treatment, consumption and requirements of every mineral and metal of economic value.

(*b*) To ascertain the scope of the existing agencies, with a view ultimately to avoid any unnecessary overlapping that may prevail.

(*c*) To devise means whereby the existing agencies can, if necessary, be assisted and improved in the accomplishment of their respective tasks.

(*d*) To supplement those agencies, if necessary, in order to obtain any information not now collected which may be required for the purposes of the bureau.

(*e*) To advise on the development of the mineral resources of the Empire or of particular parts thereof, in order that such resources may be made available for the purposes of Imperial defence or industry.

After consideration of the report of this committee, the Government instructed the Minister of Reconstruction, in consultation with the Secretaries of State for the Colonies and India, to take the necessary action to give effect to the recommendations of the Imperial Conference and the findings of the committee. Detailed proposals were accordingly submitted to the Dominion and Indian Governments, who nominated their representatives on the governing body of the bureau, and the general scheme of the bureau has now been finally ratified by the Imperial Conference.

The bureau will be incorporated by Royal Charter, and the governing body, which will be under the presidency of the Lord President of the Council will consist of the following gentlemen:—

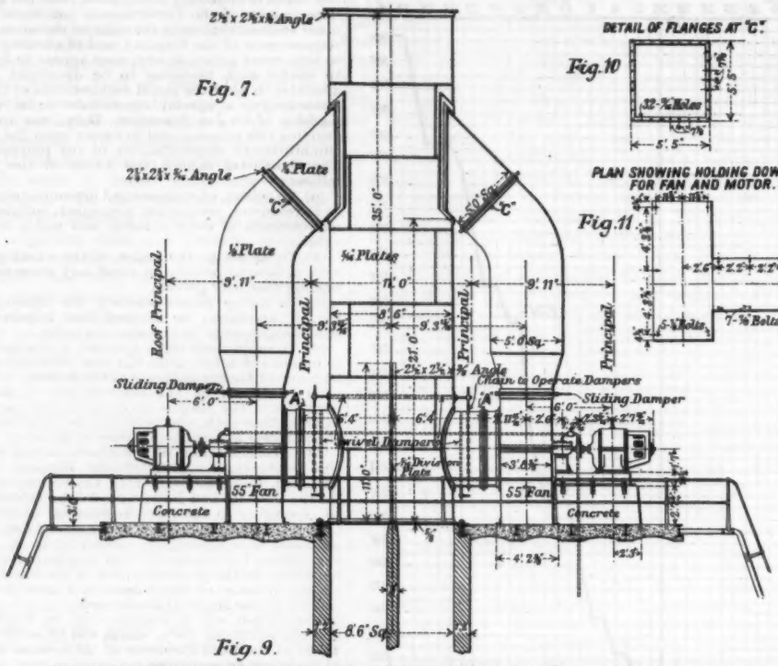
Sir Richard Redmayne, K.C.B., chairman. Nominated by the Canadian Government: Dr. Willet G. Miller. Nominated by the Government of the Commonwealth of Australia: Mr. W. S. Robinson. Nominated by the Government of New Zealand: Mr. Thomas Hutchinson Hamer, of the High Commissioner's Office. Nominated by the Union of South Africa: The Right Hon. W. P. Schreiner, C.M.G. Nominated by the Government of Newfoundland: The Right Hon. Lord Morris, K.C.M.G. Nominated by the Government of India: Mr. R. D. Oldham, F.R.S. Nominated by the Secretary of State for the Colonies: Mr. J. W. Evans, D.Sc., LL.B. Nominated by the Minister of Reconstruction (in consultation with the Institution of Mining and Metallurgy, the Institution of Metals, the Iron and Steel Institute and the Institution of Mining Engineers): Mr. W. Forster Brown, Mineral Adviser to H.M. Woods and Forests; Professor H. C. H. Carpenter, President of the Institute of Metals; Dr. F. H. Hatch, Member of Mineral Resources Advisory Committee of the Imperial Institute; Sir Lionel Phillips, Bart., lately Director of the Mineral Resources Development Department, Ministry of Munitions; Mr. Edgar Taylor, ex-president of the Institute of Mining and Metallurgy; Mr. Wallace Thorneycroft, president of the Institution of Mining Engineers. Mr. Arnold D. McNair has been appointed secretary.

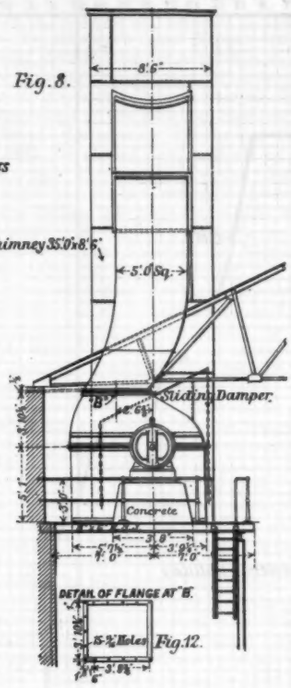
All communications regarding the bureau should be addressed to the Secretary, Imperial Mineral Resources Bureau, Holborn Viaduct Hotel, E.C.

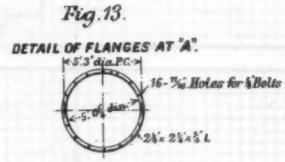
BUSINESS IN NETHERLANDS INDIA.—We read in *The London and China Telegraph* that "Notwithstanding the material difficulties caused by the present abnormal conditions, the Acting Vice-Consul at Sourabaya states that British merchants, planters and engineers have succeeded in strengthening their position and in several cases have even been able to break new ground in the Netherlands East Indies. An instance of this is the granting by the Government of a contract to supply the pipe lines for the Buitenzorg waterworks to a British firm in Sourabaya. He adds, however, that it is a matter for regret that more energy is not being displayed in canvassing for post war trade, especially in such lines as the British industry will be eminently well adapted to supply, and which even to-day are almost entirely in the hands of enemy firms. A case in point is the huge trade done in cutlery, which, to all intents and purposes, is a German monopoly. The very large stocks held by enemy firms at the outbreak of war have enabled them not only to make large profits, but also to keep their trade-marks before the middlemen, and, while the German houses are doing everything in their power to get contracts or promises of contracts for delivery after the war, nothing is done on our side to capture an extremely valuable trade, but one which, owing to local conditions and the peculiarities of the natives' taste, needs careful preliminary study. Germans are to be found in every walk of life all over the Netherlands East Indies. The number of Englishmen is in no way proportionate to the enormous British capital and trading interests in these islands. Although 70 per cent. of the capital invested in rubber is British, British planters are extremely few.

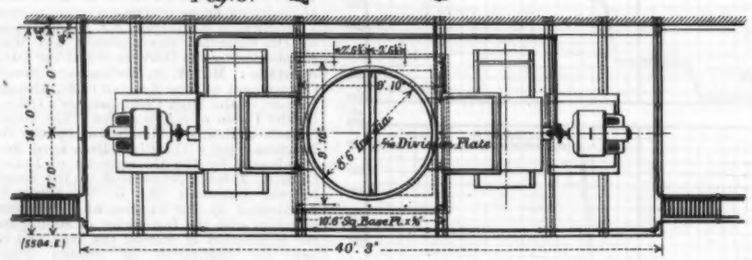
BLOWER FOR WATER-TUBE BOILER PLANT AT BRISTOL ELECTRICITY WORKS.

CONSTRUCTED BY MR. JOHN THOMPSON, ENGINEER, WOLVERHAMPTON.









On four two-page plate and on this page we give illustrations of water-tube boilers recently installed at the electricity works of the Bristol Corporation by Mr. John Thompson, Wolverhampton. The plant was ordered by Mr. H. Faraday Procter, M.Inst.C.E., Chief Engineer of the Corporation Electricity Department, after a careful inquiry into the record of boilers constructed by the same firm in service elsewhere. The new plant constitutes an important extension to the existing battery of steam generators and comprises four boilers complete with stokers, superheaters, economisers and the plant for induced and forced draught, in addition to the whole of the accessories. The contract included, moreover, all builders' work above the level of the concrete float. The general lay-out is very clearly shown in Figs. 1 to 6, Plate XII, whilst additional details as to the arrangements for induced draught are represented above.

Each boiler has a heating surface of 5,400 sq. ft. and is designed to supply steam at a working pressure of 200 lb. per square inch and at a superheat of 200 deg. F. Automatic stokers of the travelling chain-grate type have been adopted, the grate area for each boiler being 116 sq. ft.

As best seen perhaps in Figs. 1 and 3 the four boilers are arranged in pairs, and behind each pair an economiser is fitted, the arrangement being as shown in Fig. 4. These economisers have each 288 tubes 11 ft. long.

Each pair of boilers is served with a 55-in. induced-draught fan as indicated in Figs. 1, 2 and 4, some details being shown to a larger scale in Figs. 7 to 13, above. Both fans exhaust into the same chimney, which is 8 ft. 6 in. in diameter; the lower portion of this chimney separates the two economisers, and for a height of 30 ft. it is built of brickwork, the remaining 35 ft. being constructed of mild steel plates. A division plate separates the gases from the one pair of boilers from those coming from the other pair. The fans are carried on a platform immediately over the top of the economisers, but at such a level as not to interfere with the removal of the economiser tubes when necessary. Each fan is driven by a 60 brake horse-power, variable-speed motor.

With a view to ensuring a maximum of accessibility the whole of the boiler plant is carried on concrete arches sprung between steel girders. This arrangement permits of ready access to the under parts of the boilers, stokers and economisers, and greatly facilitates the removal of soot and ashes. Special gear has been provided to deal with the soot which accumulates in the economiser pits, which can accordingly be removed without interrupting the working of the plant. For the present the boilers are being operated with bituminous coal, but coke breeze can be used should this prove desirable and without any alteration to the plant.

A special feature of the boilers is the use of straight tubes which, as shown in Fig. 5, are expanded into flats pressed in the plating of the upper and lower drums. The use of straight tubes reduces the number of spares which it is necessary to keep in stock. Owing to the fact that the tubes are nearly vertical, deposits are, it is stated, not retained in them, but collect in the lower drums. Any tube in the boiler can be removed and replaced without disturbing any adjacent or other tube.

With this design of boiler it is possible to carry very great overloads, as much as 9½ lb. of water per square foot of heating surface being evaporated; this performance could have been extended but for the fact that when evaporating 9½ lb. the stokers were working at their utmost capacity. This proves the elasticity of the boiler and its capacity as a steam generator. When evaporating as much as 6 lb. of water per square foot of heating surface, the builders have been able to maintain a maximum efficiency.

Pitwood Order, 1918.—An important new Order by the Board of Trade specifies the areas from which mining districts may draw their supplies of pitwood and also fixes maximum prices, both for imported and home-grown pitwood, coming into force at once. Permits from the Controller of Timber Supplies will be necessary on and after August 12 before pitwood can be moved from one of the areas to another. Inquiries should be addressed to the Controller of Timber Supplies, 80, Newman-street, Oxford-street, London, W. 1, and envelopes should be marked "Pitwood Order, 1918." The Order is printed in full in *The Board of Trade Journal* and will shortly be on sale through booksellers or direct from His Majesty's Stationery Office, Kingsway, London, W.C. 2.

"The Flying Book."—We have received a copy of "The Flying Book" for 1918, which is edited by Mr. W. L. Wade and is published at the price of 5s. net by Messrs. Longmans, Green and Co., 39, Paternoster-row, E.C. It opens with a series of very interesting articles on aeroplanes in war, naval and commercial aeronautics, aeroplane design and construction, aero-engines, airships, &c. The various machines are illustrated by diagrams, and particulars are given concerning them as far as the present state of war makes that possible in the case of machines of the Allies. The book contains industrial directories of British, American, French and Italian manufacturers; and "Who's Who" in aeronautics; a glossary of aeronautical terms; other useful information on flying machines and 15 plates.

Danish Aeroplane Service.—Both the Aeronautic Society and the Danish Air Traffic Company, some time last year applied to the Danish Government for their support in the furtherance of aeronautic service, by means of legislative measures. Similar applications from the proper quarters were made to the Norwegian and the Swedish Government. Both the Danish military authorities and the Traffic Department have filed their statements on the subject, and the Danish Government has now appointed a commission to report on the chances of using aeroplanes or similar appliances in the service of the community, on the transport of mail and of passengers within the country, on the rules which shall apply to the use of aeroplanes for this purpose, on the expenditure it will entail for the exchequer and on the general regulations which will be needed for this new kind of traffic.

THE HEAVY OIL ENGINE.*

By CHARLES E. LUCKE, Professor of Mechanical Engineering, Columbia University, New York City.

THE heavy oil engine is of particular interest at this time because those who are familiar with the problem believe a change is coming in the situation. It is my intention to present, in a more or less informal way, some of the ideas involved in the development up to the present time and also those which lead us to believe that a change is about to take place, and in about what direction. What I say is somewhat in the nature of a prediction, although he is a bold man who undertakes to make a prediction on these matters. Nevertheless, I am inclined to have a little more confidence than usual because about a year ago I talked to you here about aeronautical engines, and showed those who were not already familiar with that fact from what a chaotic state the art of aeronautical engine construction was then emerging, and ventured to lay down some general lines of practice that seemed to be proper and a good basis for future work to follow.

Since that time this country has been drawn into the great war, and likewise since then the Liberty motor has been designed and put on a manufacturing basis. A good many ideas that were presented a year ago before the inception of that motor, and before there were standards of any kind, have been incorporated in it. A number of the things which were then not standard and which were recommended as standard have since become standard.

I feel, therefore, somewhat more confident in the sort of prediction to be made to-night on the heavy oil engine.

It may be of interest for me also to say here that as a result of the war my entire time, to the exclusion of all other things, has been devoted to the subject of internal-combustion engines for the navy service. The Navy Department has established at Columbia—about the Mechanical Engineering Department, as a nucleus—the official United States Navy Gas Engine School, and over 900 men have been given, all without any internal-combustion experience before they came, a four weeks' finishing course of training and have been turned out into the service. Of those men, the leading engineers of over 200 of the submarine chasers form a part. That work is now going on and will continue until all these boats have been manned with trained men.

It is interesting to note, also, that these boats were non-existent a year ago; they did not even exist completely on paper, and before a year will have passed from the time when they were paper things there will have been completed, and in the water and completely manned and officered by trained men, over 300 of them. Even though that is a small matter in the naval programme, it is nevertheless an accomplishment that all ought to feel proud of.

The gas engine school at Columbia University is also now undertaking to train the engineers and leading mechanics to take charge of the motors for the navy foreign flying base station service. I mention that because I want something from you in that connection; to help secure fine, competent internal-combustion engine men who are also machinists, and therefore the kind of men that can safely be trusted with the enormous responsibility of proper maintenance of an aeronautical motor, the failure of which may cause the sacrifice of life. We will not undertake to train any man who is not at the start a pretty good man—at least from the experience standpoint. We are not finding these men at the present time as fast as we need them, so I am mentioning this fact with the idea that those of you who are here and who know such men will let me have their names, or at least tell them to apply for that class of service, if they like it, and I will see what can be done to bring them in. The leading men will receive the rank of Ensign in Class 5, the Naval Reserve Flying Corps, and will have the job of Engineer Officer.

To return to the subject, the heavy oil engine. The heavy oil engine in this country has never amounted to very much. That fact itself should prompt some inquiry, because this country is the home of petroleum.

The heavy oil engine as an internal-combustion engine has so far proved itself to be capable of the highest known thermal efficiency in transforming the heat of combustion into work. Efficiencies approaching 40 per cent. are normal, and in some rare cases this is exceeded. This is not equalled by any other system that has ever been produced.

Putting those two facts side by side, you will see a cause for wonder at once. Here is America producing more petroleum than any other country in the world, and doing it for a long time back—something like fifty years—and yet the motor that operates with this oil—the most efficient known—the heavy oil engine in this land of petroleum is, compared with other classes of machinery, practically a failure. It is a failure in the sense that the business of producing it has not expanded materially, and it has been in general an unprofitable business. No one in this country has made much, if any, money in building oil engines, and a great many who have thought of going into the business with excellent prospects, good plans, and plenty of capital behind them finally decided not to do so on the record of failure to produce dividends on the part of those who are already in.

There has been from the beginning great interest in the oil engine. It is a thing attractive to the mind. Everybody thinks about it. And yet, on the commercial side, there has been very little demand—not sufficient demand anywhere to warrant any really large establishment confining itself to the production of oil engines with a competent engineering staff and research department such as would be necessary to do the thing right. This lack of demand is rather difficult to explain, but it is nevertheless real. Assume it to be a fact, without investigation, and put it down as the first of the various causes for lack of development. The next cause is the fact that this is the land of petroleum, and therefore the land where petroleum and its products are held in least value. In other words, we are prodigal of petroleum and have not the inducement, by reason of our multiple supply, to economise it. In the place where oil is so plentiful naturally it is not regarded as a valuable product—not nearly so much as in a distant country, where its cost is high. That fact makes the high efficiency mentioned before lose its attractions, and when it is remembered that the machine to produce this high efficiency is a costly machine, therein lie the elements of financial balance that turns the wrong way.

The cost of power, when it is the controlling factor—and that is usually the case in stationary installations—is made up of two charges: fixed and operating. The fixed charges are based primarily on the first cost of the engine, and the heavy oil engine has always been an expensive engine—never less than 60 dols. per horse-power and often as much as 80 dols. per horse-power. On the other side is the operating expense, the principal item of which usually is the cost of fuel. The more highly efficient is the engine, in fuel consumption, the less will be the fuel cost per horse-power hour, and therefore the more prominently this heavy fixed charge will stand out.

In all cases where the cost of power is the controlling factor these financial facts are to be laid beside the fact of the lack of demand for these oil engines. Nevertheless, as time goes on, inventors, designers, and research men are not deterred from trying out schemes, so that, in spite of this lack of financial and business encouragement, there is a very considerable degree of progress—much slower than it ought to be, but nevertheless real. Unfortunately, in this case the public in general is not informed about this progress, and therefore when, due to a change in economic conditions, the time comes to make use of all the available information on the subject, we suddenly wake up to the fact that it is in the hands of a few people, and the rest of the public knows nothing about it.

The present is a time of change, and there are two reasons for that. In the first place, the war has brought about a shipping situation which is unprecedented in the history of the world. There is a demand for ships to-day such as never existed before, but there is at the same time just as real and as strong a demand for the men to run those ships. The heavy oil engine is one of the various possible ways of driving a ship, providing the ship be not too large. Its fuel economy is a direct value in ship operation, since it gives a larger cruising radius or the maximum possible cargo capacity. It, furthermore, is peculiarly adapted to a ship, in view of the fact that we are facing a labour shortage in ship operation, and the heavy oil engine ship can be operated with less men below the deck than any other type of vessel ever produced—except, of course, the small gasoline boat. The war, then, has brought to our attention this heavy oil engine as a possible motive power for the smaller of these new merchant vessels as well as naval vessels, though more merchant than naval. And it is a fact that shipping people are considering this question to-day all over the country, but most of them are afraid to act. They would like to, as near as I can find out by talking to them, but they are afraid to act. To my mind the time is not far distant when they will have to act, or lose something by not acting.

Aside from the shipping situation, there is another reason, and that is the economic reason of an appreciation of the value of this wonderful fuel that Nature has placed beneath our country's land surface. This fuel is peculiarly adapted to this sort of use: the generation of power in internal-combustion engines directly, with the highest possible efficiency and the least possible man attendance. Fuel has been wasted in this country, especially in that region near the oil fields, just because it was plentiful. Nevertheless, we are coming to the point when the people—if not the people, certainly the Government—will be compelled to force the abandonment of the use of this fuel for all purposes where other kinds of fuel that can be had in more plentiful supplies would do as well. When you consider that oil or petroleum is the only kind of fuel that can be used in the high efficiency engine, then it becomes clear that to burn it to warm a living-room where charcoal or wood or coal of any grade would do quite as well is to commit a sort of economic crime. That feeling and the financial consequences of not acting upon the realisation of that situation will come to a climax before very long, and result in a plan for conservation of our liquid fuel or petroleum supply, so that it shall be used for only those purposes for which it is peculiarly adapted and be barred from all other uses where other things will suffice. In the natural course of events people wait for prices to bring such a situation about, but this is not a time that properly is classifiable as belonging in the natural course of events. This is a time which is distinctly abnormal and unnatural. We hear every day plans proposed and turned down because there is no precedent, with always the rejoinder that here we are in a great war for which there is no precedent, so why follow precedents in other things? We have been forced to change in a thousand-and-one things, so let us change in a thousand-and-two things, and do it quickly.

I could expand to considerable length along the lines of the economic situation with regard to the use of oil and the peculiar adaptability of oil in the internal-combustion engine, and the particular adaptability of that class of engine to the ship service, but I want you to realise that there is another field also where there is a demand slowly but surely growing up, and that all these separate demands, coupled with the growing change in the economic situation, must certainly, one piling on top of the other, produce a new condition which I foresee.

We have a real gasoline automobile industry, and it is becoming a great manufacturing industry, but it is to-day tied up to and inherently dependent upon the lighter petroleum distillates. There is no highly economical gasoline or kerosene engine, and every reason leads us to believe fundamentally that none can be produced on the present system. To make our automobiles and motor trucks and tractors run, and to make our available sources of fuel supply last, there seems to be only one solution, and the leading engineers and mechanics in the automobile industry are beginning to talk about that solution: the adaptation of the heavy oil type of engine to the high-speed class of service which such as the automobile and the tractor require. It is coming; there can be no question about it. If anybody is able to-day to produce the high-speed type of engine necessary, even though it costs more money to build, rest assured it will be adopted very quickly.

There is a third field, and that is the field of direct-connected electric generating sets. For a long time in the gas-engine business we built engines to drive generators in a kind of haphazard fashion. As time went on a particular type of outfit began to appear—a direct-connected, high-speed generating set, with engine and generator on one base, self-contained, the best example of which, on a small scale, is the Delco lighting outfit, which is being sold at the rate of over 50,000 sets a year now, all over the country districts. There are corresponding units of other designs in larger sizes. The fact that these sets are generally confined to gasoline limits their use, because in many places gasoline is unsafe to use; in other places it is not obtainable; in still others the cost of it is prohibitive. It is apparent that if we had the heavy oil engine adapted to that class of high-speed, multicylinder service, and with the necessary degree of regulation, it would open up still another field.

So in the field of application of the heavy oil engine I see just ready to be invaded these three things: First, a widened use for ships; second, a new use in the automobile type of motor; third, a corresponding new use for direct-connected, high-speed electric generating sets. Whether they be used on land or aboard ship, it does not matter. If they are designed right they are serviceable in either place.

It is of interest, and particularly pertinent here, to review some of the ideas that have been developed to date, and some of the suggestions available as lines of possible development in the direction of real progress. And this review I divide, for the purpose of clarification, into two topics—functional and structural.

Under the functional come all those questions connected with the supply of air, the supply of oil, the establishment of the proper relations between the oil and air to give the desired control of combustion after the necessary compression—in fact, all those physical processes involved directly in the development of the power within the cylinder.

Under the head of structural would come all those principles of type arrangements or typical part forms, and proper proportions of the metal structure that houses these physical processes and there produces a machine.

The first item under the functional discussion is that of charging the cylinder with air, and this is carried out by either the so-called and well-understood 4-cycle system of two valves per cylinder, or by any one of several 2-cycle schemes. Of the 2-cycle schemes there are a number. First we have the ordinary crank-case pre-compression chamber, which is barred from any engine of more than diminutive size, because the closing of the crank-case prevents access to the working parts, in addition to imposing other bad conditions. The first step in avoiding the difficulties of the closed crank-case, which are prohibitive in any real engine, comes when the connecting rod and crankshaft are left open and the front end of the cylinder closed, the front end acting as a pre-compression or air-charging chamber in conjunction with an air reservoir, which is necessary, so that the pressure in the front end of the cylinder cannot rise too high.

This front-end compression arrangement has certain faults that have led to the design and more wide use of others. For example, it is not possible in the oil engine of the 2-cycle sort, with the front-end pre-compression chamber, to put into the motor end a volume of air equal to the piston displacement: the volume must necessarily be less than the piston displacement measured at atmospheric pressure. That being the case, some of the burned gases or products of combustion cannot be expelled, and, at the same time, the residue is hotter than it otherwise would be. To correct that, the alternative schemes of a step piston or a separate scavenging pump have been developed, more particularly the latter. The step piston is the first of the scavenging schemes, and is a scavenging scheme because the volume swept through by the step of the piston may be made larger than the volume swept through by the motor piston proper, and the excess of this displacement is the scavenging displacement. By means of it more air can be put into the motor cylinder per charge than can possibly stay there at atmospheric pressure. This being the case, the burned gases may be more completely expelled, and, what is much more important, the residue of the gases left there would be much cooler before the next compression starts.

This step piston has certain faults of a structural nature which need not be detailed, but which are responsible for the wide use of the alternative scavenging scheme of a separate low-pressure compressor, built somewhat along the lines of the old-fashioned blowing engine. This arrangement is usually double-acting, so that one such scavenging pump will serve two single-

* Presented before the Engineers' Club of Philadelphia, January 29, 1918.

acting 2-cycle motor cylinders. With it the 2-cycle engine can then be made to perform all the things that the 4-cycle engine can do, except as to the negative work involved in the pre-compression of that surplus air; so that, while the two engines may perform somewhat the same, the 2-cycle form will be necessarily less efficient by the lost or negative work, and, at the same time, some of the so-called simplicity of the 2-cycle engine has disappeared. So completely has it disappeared that it will be found that the weight per horse-power has grown in the 2-cycle to be substantially the same as the weight per horse-power in the 4-cycle. That is to say, when you start with the simple 2-cycle idea with the hope of getting half the weight per horse-power, because of twice the number of impulses from the same amount of metal, then you have to add this and that and the other thing, and by the time you have got through adding enough to make it a real working engine the weights of both types are just about the same. Therefore the 2-cycle as compared with the 4-cycle, as to weight, might be called substantially equal. But there is an inequality in another direction. The 2-cycle, acting with more impulses per minute in the same volume, will run hotter and load the same sized bearings to a higher average bearing pressure, and, as a consequence, size for size, the 2-cycle will give more trouble with burnt pistons and overheated bearings than the corresponding 4-cycle. These are just a few of the reasons why this much-mooted question of 2-cycle *versus* 4-cycle as a means of air charging remains a controversial matter rather than one of settled engineering practice. My own personal opinion about the matter is this: That in the smaller size, let us say up to 100 h.p., or 200 h.p. maximum, the simpler form of 2-cycle, not with the separate scavenging pump, is a rather good thing and practical. In the next range of sizes, from, let us say, 500 h.p., the 4-cycle works out best in the long run, and from that point up the pendulum swings the other way toward 2-cycle with scavenging pumps as matters stand to-day. But in the larger sizes the art is most undeveloped, and most of the uncertainty as to what is the proper engineering practice concentrates right there.

The next item under the functional discussion is the introduction of the oil, to form either an explosive mixture for explosive combustion or to prevent the forming of an explosive mixture so that the oil may burn non-explosively. Before examining the means of introducing and controlling combustion of the oil, I want to point out the fundamental and controlling value of a compression before injection on the one hand, and of the rate of oil burning following the right amount of compression, on the other. Consider the former point first. It can be demonstrated, and it is pretty generally understood now without demonstration, that, other things being equal, the more the air charge is compressed before the introduction of the oil the higher the mean effective pressure will be; and that, of course, is a prime factor in power and, at the same time, the higher the efficiency, or smaller the fuel consumption. It may therefore be said with practically no reservation that in an oil engine as much compression should be carried as is possible. But that is not all. After the compression has been completed, the oil must be introduced either at that time or just previously, so as to produce a suitable and proper combustion line of one of the two characteristic types or mixed.

The two characteristic types of combustion line are, first, the vertical combustion line produced by an explosive mixture, and, second, the horizontal combustion line produced by a gradual introduction of the oil, the oil burning as it comes in, and which latter system has been called the Diesel system. It is clear, of course, that we might burn part of the oil explosively, raising the pressure a fraction of the maximum, and burn the rest non-explosively, without further change of pressure. Or we might have such a slow introduction of oil as to cause the combustion line to drop as the piston moves out on the working stroke. The two types of combustion line are (*a*) the vertical explosive, and (*b*) the horizontal non-explosive, or Diesel, forms. Now, of these two methods of oil combustion as to rate, which should one choose? That question should be settled before considering the means of introducing the oil, because one is not warranted in spending time in determining how to introduce the oil until there is first a decision as to what end is to be accomplished by it. In other words, we must establish the specifications before undertaking construction.

It will be found, by comparing the full diagrams for those two combustion lines, with the same amount of oil and expansion, of course, following both, that about the same mean effective pressure is possible with both or with either. That is to say, so far as power is concerned, there is no choice. But, on the other hand, when you compare efficiency or fuel consumption, then this startling fact comes out: That the constant-pressure or Diesel kind of non-explosive combustion is capable of only half the efficiency of the other kind of combustion, the explosive sort. To put it a little differently and more precisely: If the fuel be burned explosively after compression, then an efficiency can be produced with a corresponding fuel consumption equal to that obtainable with the non-explosive Diesel combustion when the latter has twice the compression of the former. Again, to put it in still another form: A Diesel diagram with nearly 500 lb. compression produces no better efficiency or fuel consumption than an Otto cycle diagram with 250 lb. compression. There is therefore absolutely no doubt on fundamental ground as to which of these two possible modes of burning offers the best promise of results. They are equal in power possibilities and nearly two to one in efficiency with reference to compression. When I say the latter, do not misunderstand. Do not think I mean to assert that the Otto can give and always will give twice the efficiency of the Diesel—not at all. They can be made exactly equal in efficiencies and fuel consumptions with selective compressions, but when the compression is thus selected to do that thing it will require twice the compression with the Diesel as will be required with the Otto arrangement.

This is particularly interesting when you consider that fully 90 per cent. of all the development work that has been done with this heavy oil engine has been done with the less promising Diesel cycle, and the very promising Otto cycle has been almost entirely neglected. I say it has been neglected, and yet I do not mean that. It has not been neglected by those people who understood the possibilities—the students of this subject. It has not attained the popularity or the standing in a commercial way of the Diesel.

In this functional study the next important consideration is the compression itself, and the relation between the degree of compression and the mode of combustion, or control of combustion. The oil has to be ignited, and there are various ways of igniting it. It must not, however, be ignited until the right time comes; that is, not until a sufficient degree of compression has been executed —whatever is desired. Therefore there must be an igniter, and the ignition, as a process, must be under control. Now, the ignition, will always take place whenever any fuel in contact with air reaches the ignition temperature. The air under compression is rising in temperature and is approaching or passing the ignition temperature in that process of compression. Somewhere or another in the process of compression, if it be carried far enough, ignition temperature will be established, and ignition will inevitably occur, if there is any oil in contact with the air.

It is therefore essential, in considering the limit of compression in its relation to the introduction of oil, to have some kind of mental picture, and preferably exact figures, as to the way in which the temperature rises in compression, especially with reference to the ignition temperature as a basis of reference.

The ignition temperature of these heavy oils is a somewhat uncertain physical constant, but from my experience I am inclined to think this is very close to 950 deg. F., or near enough to that for practical purposes.

To bring this matter before you I have prepared a little table here (see table below). This table shows at the left, first column, initial air temperatures of from 200 deg. F. to 600 deg. F. before compression. Starting with these temperatures, then, to reach ignition temperature it would be necessary to have the compressions indicated in columns 2 and 3. To reach temperature of 200 deg. less than ignition temperature the compression would be as shown in columns 3 and 4. To reach a temperature of 200 deg. F. over ignition temperature the compressions required are shown in columns 5 and 6. Or, for 400 deg. F. over ignition temperature, the compressions of columns 7 and 8.

To explain further, starting with atmospheric air at a temperature of, say, 70 deg. F. in an engine-room, it is drawn into a cylinder, and is bound to become somewhat heated on its way. It will become heated by contact

Compression v. Initial Temperature v. Ignition Temperature (±).

Initial Temperature.	Compression, Pounds/Square Inch above Atmosphere (14.7) with 0.1 Lb. Valve Drop.							
	Ignition Temperature of 950 deg. F.		200 deg. F. Below Ignition.		200 deg. F. Above Ignition.		400 deg. F. Above Ignition.	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
200	190	293	104	152	305	511	467	800
300	110	155	58	79	181	279	282	460
400	67	92	34	42	114	165	175	275
500	41	52	18	22	75	101	118	174
600	23	31	8	10	47	63	79	107

Based on $S = \begin{cases} 1{\cdot}33 \\ 1{\cdot}40 \end{cases}$; $P = 14.6 \left[\left(\frac{T \text{ final}}{T \text{ initial}} \right)^{\frac{S}{S-1}} - 1 \right]$

with the hot intake ports, sweeping over the intake valves, sweeping against the interior cylinder walls, which are very hot, especially in large engines with thick metal, and finally it mixes inside with the hot products of combustion from the previous shot. So, to say that this 70 deg. F. air will rise 130 deg. F. and have a temperature, therefore, of 200 deg. when compression starts as a very moderate estimate. It is never less than that, and that is the reason I have made this the minimum figure. It might easily be much more than that, especially when it is considered that in some of these engines the interior is red hot in spots. In some of them the whole wall, especially the hot bulb type, is deliberately kept red hot as an igniter. It is quite clear that any products of combustion or air in contact with that red-hot spot might easily approach or exceed a temperature of 600 deg. before any compressing is done at all. So I make the temperatures before compression range anywhere from 200 deg. to 600 deg., and there is even justification for going further.

Now, when the compression starts the pressure follows the general law given at the bottom of the table, and from that certain variations follow; but we are not quite sure as to what value the exponent S has, although we do know it cannot be larger than 1·4. We know by experience it is not less than 1·33. So, for each one of these values I have calculated two figures—the compression pressure in pounds per square inch above the atmosphere—and you see here that to reach ignition temperature with 200 deg. initial temperature would require 190 lb. compression minimum to 293 lb. maximum —actually somewhere between; it is difficult to fix it any closer. Whereas, if the initial temperature was 600 deg., then the ignition temperature would be reached in that same cylinder with a compression of only 23 lb. to 31 lb. That brings out in the most striking fashion this fact: That if the fuel is in contact with the air in the cylinder during compression, then the amount of compression cannot be very large in any case without producing an uncontrolled pre-ignition. And, more important still, if any part of the oil and air is very warm before compression starts, then practically no compression can be carried at all. And, if you cannot carry much compression, then you have a very high fuel consumption and a very low efficiency. An engine carrying such low compressions as are here required would burn nearly 2 lb. of oil per hour per horse-power, whereas the best engines are to-day running on about four-tenths of a pound—a ratio of five to one.

Now, suppose an igniter that was itself under control, and fuel in contact with the air in the cylinder. How much can we compress it without any danger of pre-igniting it, so that when we want to fire it can be fired with the igniter that is under control? I suggest that 200 deg. margin is about as good as can be estimated. Let us limit the final compression temperature to something like 200 deg. under the ignition temperature, in which case these are the allowable compressions: With 600 deg. initial temperature, the final compression pressure is 8 lb. to 10 lb.; with 200 deg. initial temperature, 104 lb. to 152 lb. (see table).

On the other hand, suppose that the system was such as the Diesel, where the air temperature itself is to serve as the igniter. In that case to insure ignition, we should have a margin of about 200 deg. in the other direction; that is to say, the air should be compressed to a sufficiently high pressure not only to produce ignition temperature, but 200 deg. more, in which case the last two columns give the compressions that are necessary. Should the oil now be introduced into the cylinder by means of compressed air to make a fine spray and scatter it through the charge of air, in accordance with the general practice, then it must be remembered that this air jet which is doing the spraying and the scattering is itself exerting a cooling action. Consider 1,000 lb. or 1,200 lb. pressure of air expanding through the spray valve into a cylinder with about 300 lb. or 400 lb. or 500 lb. compression pressure, and it can readily be seen that there is a very considerable cooling action right at the jet. That it will act to prevent ignition, and, to make sure that the oil will ignite in spite of such cooling influence at the point of oil injection, it is necessary to carry the compression still higher. Let us provide at least 400 deg. over ignition temperature, in which case with an initial temperature of 200 deg. we would require something between 467 lb. and 800 lb. compression. With 600 deg. initial temperature we could secure this 400 deg. above ignition with anywhere between 80 lb. and 100 lb. compression.

These figures should be made the subject of some study and be used in considering the various structural arrangements, because in them will be found a key to the question: Why cannot this type of engine—this arrangement—be efficient? And why is the other arrangement highly efficient? Here also will be found the key to the question of how we should proceed to make the less efficient one more efficient. These three elements stand out:—

First, is the fuel in contact with the air during compression, or is it not?

Second, if the oil is in contact with the air during compression, is the region of contact all of low temperature, all of high temperature, or any part of it a high temperature region when the compression starts? The initial temperature has a great effect on the degree of compression needed or permissible.

Third, if the oil is not in contact with the air during compression, but has to be introduced subsequently, how should it be introduced with reference to the igniter? If the air itself is to be the igniter, then a certain high value of the compression must be obtained, or the engine will not run. If the air itself is not to be the igniter, then what kind of an igniter can we provide? We will look into that question.

All the first oil engines to attain commercial success had vaporizers. That is to say, there was some element, the duty of which was to heat the oil alone for later air mixing, or to heat the oil and air together, to produce a vapour air mixture. It matters very little as to what were the details of those arrangements—whether one produced a heavy carbonising action and another did not. They are all one as regards this point of controlling importance: The mixture when formed by any such vaporizing system is necessarily a warm or a hot mixture. Just how hot it has to be depends upon the vapour pressure of the particular oil, or rather the heaviest constituent of that particular oil, and I will give some figures to make it clear. A 60-deg. Baumé gasoline vaporising in air requires a temperature of about 100 deg. to 110 deg. The ordinary lamp kerosene of 150 flash point vaporizing in air requires a temperature of 250 deg. A navy fuel vaporizing in air requires a temperature of 420 deg., and so on. One could go on with any grade of oil or residue; for each there is some temperature at which the vapour of the oil can be produced in the right proportions for combustion and in contact with its air, without residue and dry. The heavier the oil the lower its vapour pressure or that of its heaviest constituent, then the hotter that mixture must be to be a gaseous mixture; and the hotter it is, according to this table, the lower the compression it can stand without self-igniting. Therefore only those fuels that have high vapour pressures or that can make cold gaseous mixtures can be treated with the whole mass under compression. Those oils which are within the heavy class of oils, and have so low a vapour pressure as to require 300 deg. or 400 deg. initial temperature outside the engine plus a couple of hundred degrees rise in temperature coming into the cylinder, can be compressed hardly at all.

Therefore such heavy oil engines cannot by any possible conformity with Nature's laws be efficient. It is fundamentally sound that all those schemes for heavy oil engines that involve vaporizers are utterly incapable of producing an efficient engine.

For some reason or other everybody playing with this class of machine in the early days seems to have been absorbed with the idea of cooking the oil; they seemed to feel that it had to be roasted to death, and then wondered why they could not carry any compression, and why the efficiency was so low and the fuel consumption so high. This fundamental impossibility, against which mechanical ingenuity is absolutely helpless, never hit them at all; and that situation has lasted from the early 'seventies up till to-day, and people are still inventing schemes of this kind.

It is perfectly clear that to produce a high efficiency, and at the same time a fairly high mean effective pressure in the interest of high power, the first and fundamental requirement is not only high compression, but to keep the oil away from the air until the time comes to burn it. By keeping the oil away from the air during compression any compression you please is yours for the asking. It is purely a matter of mechanical clearance between the piston and cylinder head. Therefore it would seem possible to secure almost any efficiency in such an engine with the delayed introduction of oil under the system which has received the name—and a very good name—of late-injections engines. Late injection is fundamental to efficiency. I will not say there is no limit to the efficiency, but it is far beyond the common old practice when this principle is adhered to.

Now the late-injection principle of working is highly developed mechanically only in Diesel engines, and therein you see there is a little scientific engineering anomaly. The desired and necessary principle of high compression with delayed injection has been developed in its application to the less promising type of cycle—the Diesel; and the more promising type of cycle, the Otto—that which promises a given fuel consumption with half the compression of the Diesel—has been delayed; so that our engines have been highly developed along the less promising line without scarcely any development at all along the more promising line. Do you wonder, then, that with the success we have had with the less promising we may expect and look forward to much greater success with the more promising field when it is vigorously followed up?

We have come now to this point: That after compression we are to introduce the oil, and the oil may be introduced in such a way as to produce an explosion or to burn at substantially constant pressure without explosion. I want to point out to you next the controlling means in use for doing either one of those things or both of them.

First, as to the Diesel: At the time the oil is introduced the temperature of the air is something higher than the ignition temperature—200 deg., 300 deg., 400 deg., or 500 deg. higher than ignition temperature—and so far in all these engines the oil has been introduced and sprayed by the aid of compressed air. How is the feed of oil controlled so that the rate of combustion shall be just enough to prevent the pressure falling along the re-expansion line, but kept substantially constant? That is entirely a matter of spray-valve design. If you set yourself the problem—especially those of you who have not worked on this problem—of designing a scheme to squirt oil into a cylinder against 400 lb. or 500 lb. compression pressure at a graduated rate for 10 per cent. to 15 per cent. of the stroke, so as to hold the pressure constant, the oil burning as fast as it enters, you will find some little problem on your hands, and I venture to say that eight out of ten men will start with some kind of cam-driven pump. Now, that will not work at all. The thing that is relied upon is the tendency of the oil to stick to a metal plate. To make that clear, consider the ordinary spray Diesel valve with a fairly heavy stem in a casing. Beyond it there is a graduated orifice outlet, which is the spray orifice and is changeable in size to suit the viscosity of the oil. The oil is pumped into the chamber or space between the casing and the valve stem by a pump which has only one duty to perform, and that is, measure the amount, not time or graduate of the injection. That cannot be done—or it never has been done. I do not think it can be done. The oil, in the ordinary course of events, is put into the spray-valve chamber before the injection is wanted, and it will run down to the bottom more or less fast. If the valve be lifted and the oil itself has reached the bottom or valve seat, the first thing to happen after the opening of the valve is a squirt of solid oil with no spraying whatever. In an instant the oil is all out, and, instead of maintaining a graduated combustion for 15 per cent. of the stoke, we have a lump of oil squirted in without spraying or graduation. There will be a certain amount of combustion, but only part will burn; the rest makes a little lump of carbon.

Now, to secure graduation of oil feed, all that has been done is to stick a lot of plates with holes in them in the space between valve stem and casing. These plates have definite thickness spacing and drilling; sometimes they are given special forms and surface finish, each designer adopting an air of great mystery about his arrangement, and claiming absurd superiority over his rivals.

All that these things do in the oil chamber is to provide an extended surface to which the oil naturally tends to stick. It might be filled with shot and it would no doubt work just the same. The oil is pumped into this chamber and when the valve is pulled open the oil tends to travel down, partly by gravity and partly by the surface frictional influence of the air on the oil. The oil, however, is sticking to that labyrinth surface. The oil chamber is nothing but a mechanical labyrinth. That is what it is called for want of a better name. And that is the only means that works as a graduator of oil feed, except one. The other one surrounds the valve stem by a sort of Venturi tube casing, between which and the valve body is found the oil-receiving chamber. There are two holes in the Venturi partition between the oil chamber and stem chamber, one from the Venturi throat to the bottom of the oil, the other imposing the total air pressure on the oil surface. When the valve is open the compressed air flowing through impinges on that hole to the surface of the oil and builds up its total pressure, while at the same time the other hole, being at the throat of the Venturi, is subjected to a lesser pressure by the air velocity head, thus developing lifting tendency on the oil, and we have a regular vacuum flow injector. This action of the former one of the labyrinth forms the basis of all the schemes for graduations of feed of oil from the spray-valve body to the spray-valve nozzle, so that the oil feeds during the required period of time at a more or less steady rate to this nozzle, and it is torn to pieces or sprayed by the velocity of the air issuing from it. It is clear that with this arrangement the rate of oil flow, the time of oil feed, and the rate of combustion will vary with the viscosity of the oil.

Should such a valve be adjusted by the spaces and orifice size to give the required feed for a given oil, and then supply an oil of lesser viscosity, or may be the same oil supplied hotter, or really a less viscous oil, then it will discharge much more rapidly, and instead of a horizontal combustion line there will be a rapid rise of pressure somewhat like a slow explosion. This indicates what is necessary if we desire to make a spray nozzle suitable for producing an explosion. To produce the explosive mixture and secure explosive combustion of oil with the spray nozzle, the first step necessary is to reduce the flow resistance in the body of the nozzle by removing a considerable amount of the labyrinth surfaces or by reducing the viscosity of the oil by heating it. As a result the oil will be discharged much more rapidly, and if enough resistance be removed from such a spray nozzle it would give a substantially instantaneous injection of oil as a liquid spray. If that occurred we would have a more or less finely divided spray scattered through the mass of compressed air, and if the air is not up to ignition temperature, then we would have produced what might be called a liquid explosive mixture, ready for any kind of ignition that is handy. It is a liquid explosive mixture because no attempt has been made to vaporize the oil. All that has been done is to make really fine fog of liquid drops suspended in the air, scattered through the combustion chamber. To get such an explosive mixture or charge ready for ignition it is necessary that no part of the interior walls or the air itself touched by the oil be up to ignition temperature, because if the air should be up to ignition temperature, as would be the case with the Diesel, then the oil would ignite as it came in, before the oil spray charge was scattered through the air. To obtain the explosion it is necessary to get all the fuel into the cylinder and scattered through the air before it is ignited, just as with delay electric ignition. On the more desirable Otto cycle with its explosion it is necessary to prevent the air reaching ignition temperature during compression; it must be capable of igniting the oil, and the ignition, by whatever means is relied upon, must itself be delayed long enough to let the whole charge of oil get in the cylinder, because unless it is in there is nothing that can explode.

Now as to igniters: The common thing has been a hot plate; sometimes a bulb of spherical form with a neck; sometimes a hemispherical bulb without any neck, just forming a cylinder head; and sometimes all sorts of weird curves and twists and shapes—every one of them the subject of a patent. Now, of that collection, what is good and what is bad? There is a simple way of sizing it up. The hot metal—that is, the igniter—must be so related in position to the injection point that no part of the oil reaches the hot plate before all of it is in the cylinder, and the shape such that no part of the oil reaches the hot plate before any other part.

Let me illustrate and you will see the force of this principle. Consider a cylinder with a spray valve at one edge of a nice hemispherical plate, red hot, the oil being sprayed at an angle toward the plate. There have been many made like that. The hot plate comes up quite close to the injector, which discharged a more or less conical spray. Some of the oil will strike the hot plate before the oil is all in the cylinder and considerable of the air. The first oil that hits that plate is going to fire the charge, or so much as has entered, and much of the air is utterly inactive and cannot do anything, as it has received no oil. At the same time, an explosion of part of the charge has taken place and the rest is still coming in. What does it meet on the way in? A red-hot—yes, a white-hot—mass of inert gas. What will happen? Nothing but crack, liberating free carbon and carbon monoxide. The unused and unmixed air leaves free oxygen in the exhaust, and with it the unburned fuel appears as carbon monoxide and much free carbon with plenty of solid carbon cake inside. A very low mean effective pressure and low efficiency will result, and the engine will be very dirty.

The ideal condition is that in which no part of the oil strikes the igniter sooner than any other part, and none of the oil strikes the hot plate until all the oil is in. Now, what kind of arrangement would give that? Suppose we had a spray valve making a cone-like spray discharging axially in a hemispherical head, the centre of which is the spray orifice. Then at the time the oil at full load had reached this hot ignition plate the last oil would have come in if the dimensions were right. That would be in conformity with the principle laid down. That arrangement will give anywhere from 50 per cent. to 100 per cent. more mean effective pressure than the non-symmetrical arrangement previously described, and with it any compression you please may be carried. It does not matter how hot that latter plate gets, whereas the former has to be run cool on the side where the oil first strikes and yet hot enough elsewhere not to miss fire. At full load it tends to get too hot and pre-ignite and knock its head off; with a light load it fails to get hot and fails to fire at all. And so the engines in that class are always provided with some kind of scheme to prevent getting too hot at heavy load and too cold at low load. The popular water-injection scheme usually does nothing but wash the lubricating oil off the cylinder wall.

For a long time, practically throughout the whole history of this art, this condition of necessary relation between the spray valve and the hot-plate igniter has not been realised, and yet hot-plate igniters have been in almost universal use. Now hot-plate igniters themselves are a bar to progress, because if we use a hot-plate igniter it has to be an outer wall. It has to be an outer wall so that you can start it with a torch and still not burn up. An inner wall cannot be started. A hot plate submerged in a cylinder cannot be started, because you cannot get a torch at it from the outside. If a hot-tube igniter be provided for starting and an internal plate relied upon for running, as is sometimes done, then you have no control over that hot plate at all and it will burn out. So a hot-plate igniter has to be an outer wall to be practical, and when you have made it an outer wall to be practical, then it is not really practical, because it limits the size. That red-hot plate lacks tensile strength. To be sure, a selected grade of cast-iron can be found that will not lose too much tensile strength, but nevertheless it is very weak in proportion to what it might be. As cylinder sizes go up—and I have already indicated that one of the great fields of need for the heavy oil engine is ship work, which calls for cylinders to go up just as high as we can make them go—then the external hot plate is barred. It is not good because it is too weak structurally. Here is the place, then where the functional problem leads to a structural debarment and where progress into the larger sizes requires an abandonment of the red-hot plate as an igniter—or at least a very material modification. If we can get along without it at all, then we need not fool with modifications, and as a result of that thought many people have tried various other schemes, and there is now being attained some success with electric igniters and with moderately-warmed internal hot plates, which are more properly called "warm" plates. Suppose, with reference to the latter, that we have a 300-deg. internal temperature and one would stop just short of ignition. Suppose we had a 300-deg. initial temperature; then for practical reasons about 279 lb. compression (see table) would carry the entire air above ignition temperature 200 deg., and that would not be practical with late injection. If, however, the initial temperature of the air were lower, or a sufficiently lower compression were selected, we could come within 100 deg. or 200 deg. of ignition temperature and still have a very substantial compression. As a matter of fact, it is perfectly feasible to use compressions up to 175 lb., approaching 200 lb.—possibly more—without reaching ignition temperature, provided the initial air is not too warm. Suppose we were injecting straight toward the piston and we had a spot of metal on there that did not get red hot, but raised the temperature of the air right next to it 200 deg. or 300 deg. higher than elsewhere. That is all that is necessary for ignition, and that is one way the thing might be done. A cold external wall for strength, a warm internal spot at the maximum distance from the igniter, not red hot but sufficiently warm to supply a couple of hundred degrees difference between the temperature attained by compression (which is not high enough to produce ignition) and the amount necessary to actually produce ignition at that one spot alone.

We do not know much as yet about that scheme, except it is possible to run that way. Whether it can be developed into a practical controllable thing remains to be seen. I am inclined to think it can. If it can, then one serious bar to the increase in size and more extended use of the Otto cycle engine has been removed and a new field of most interesting and valuable possibilities opened up.

Without that, however, there is still another way of proceeding that is receiving some attention. For a long time back it has been known that with a sufficiently fine and proper kind of spray of oil into air an ordinary spark plug would serve as an igniter. With the wrong kind of spray and plug the oil would collect at the spark plug and short-circuit it, but a spark plug can be made to ignite the right kind of spray just as positively as it ignites a gaseous mixture. An apparatus involving the lighting of sprays by spark plugs is going to receive considerable impetus in the near future.

As to engine schemes: Suppose we had a thoroughly cold interior engine—an engine the walls of which were all cold, just as cold as we can get them, and to my mind you cannot get them cold enough for a good practical oil engine—the colder the better. In to that cold cylinder we admit a charge of air and compress it, but not sufficiently to produce ignition, and when we get a sufficient compression to produce a highly economical engine as to oil and sufficient to produce a mean effective pressure approaching 100 lb. per square inch, then ignite with this spark plug. That can be done, and it is a most interesting possibility. It is particularly interesting because in conjunction with it it is possible to use a modified oil spray.

With the standard Diesel engine the oil-spray valve is supplied with compressed air under 1,000 lb. and more. Now, in the actual running of these engines the air compressor to supply that air and the air storage are just about as big a nuisance as the engine—sometimes, in fact, and often, more. If we could get rid of that, it would be a splendid thing to do. A "solid" spray is therefore a highly desirable thing.

So far we have succeeded in making a number of engine solid-spray valves that work quite well, and they work

so well that I feel confident that the end of the compressed air spray is drawing near, and that thereby we are going to eliminate another big source of trouble. I am not sure that the solid injection spray I have in mind will work on the Diesel engine, because the Diesel engine requires a graduated feed, and I am not at all sure that the principle of action of the solid spray can be adapted to the graduated feed. It works splendidly with the instantaneous feed for the Otto cycle or explosion engine. There is only one principle that need be kept in mind to explain the many ways of working out the solid spray, and that principle is pretty old. It is the principle of the navy fuel oil-burning spray for boilers. The navy and other ships cannot afford to use compressed air or steam for spraying oil, as is so common on land, because they have not the fresh water with which to produce this steam. They are therefore compelled to use a mechanical spray, and this type of spray has been very highly developed. It involves nothing more than a minute orifice from which the oil is discharged with a combined motion axially through the hole and rotary as it comes out, the rotary motion being developed before the oil reaches the hole in a rifling tube or tangential feed passage to a little whirl chamber just back of the spray orifice. By giving the oil a whirl behind the spray orifice with a proper exit from the orifice it issues with a motion in two directions—axial and rotary—producing a sort of solid conical spray that is fine and works well in an engine. By making the passages small enough in such a spray valve so that they are practically capillary, then a direct-acting pump plunger slamming against the solid column of oil will make such a spray without any dribble at the ends of the spray period. Remember that no dribble at the end or beginning of a spray is permissible, because every drop that dribbles carbonises. To avoid the dribble the only thing necessary is to get the passages substantially capillary in size, and that is not difficult. At first glance it would seem as if that boiler-spray valve could not be made to work with rapid intermittence, but it can and is so working to-day.

Now a word or two on the structural side. We may assume that this functional question has in it considerable undeveloped possibilities, and that these are not mysteries, but are lines of purely rational progress, the key to which we have in every instance, and nothing is unknown except how far you can go. We know the route every time; but we do not know how far we can go. Assuming that you can see with me in your mind's eye non-Diesel, late-injection, high-efficiency oil engines working as well as the Diesel—or better—then arises the question: How should the structure be built? Are there any lines of standardisation that can be well and properly applied there? Or is every designer to regard himself as the one selected by the Almighty to produce something that no one else ever made? For some strange reason, that seems to be in the minds of almost all oil-engine designers. While for years we have been building shafts, frames, and engine structures for steam engines and similar structures for pumps and compressors, just as soon as an oil engine designer gets his hand over a drawing-board he wants to throw all that experience away and get up some other thing and make more trouble than do the parts that are peculiar to the oil engine.

The point of view to take with regard to this structure is this: There is no essential difference in kind, except the cooling problem, between an oil-engine cylinder and a steam-engine cylinder. The difference is one of degree in the structural problem. There is no essential difference—certainly none in kind, between the problem of the frame and the bedplate and the rest of the running gear of the oil as compared with the steam engine. That being the case, these queer arrangements that have crept into the oil engine field and that have become more or less standard there, quite contradicting all previous experience and established custom with the more firmly established steam engine, cannot be accepted. There is no difference whatever in the design of a column to support a bridge, a pier, or a building, or to support a statue; all that counts is the load to be place on it. And yet the oil man has persisted in carrying out his structure from cylinder down to bedplate on radically different lines than have long been standard with steam. The result is hopelessly bad. Let us bring out some of our good old designers who understand the designing and building of structures to carry loads, and I would not tell them anything about the oil-engine peculiarities at all. Some other man is taking care of that. Then we will get somewhere.

Just to point out one or two things, to illustrate what I have in mind, consider the most widely used Diesel cast-frame structure extending from bedplate to cylinder head, and being an axially-expanding cylinder line. This cylinder line is a stressed member, the stress being bursting stress, with 400 lb. or 500 lb. per square inch normal pressure at the top, and possibly an accidental maximum pressure with a pre-ignition pressure of twice that amount—1,000 lb. or 1,200 lb. per square inch. Now we certainly know how to build cylinders to withstand bursting, so this is not peculiarly an oil-engine problem, except that its expansion must not be restrained. That cylinder structure is inside of a heavy casting and held at the top. This casting is practically an "A" frame with a cylindrical extension at the top; the cylindrical extension forms the water-jacket and is faced at the top on which the cylinder line flange rests. There is a slip joint at the other end of the line to allow of longitudinal expansion of the cylinder line barrel with reference to the jacketted frame. An engine built along such lines as that is fundamentally wrong, because the jacket is at the same time a frame. What is its principal duty? Its principal duty is to hold water—and anything that will hold water will do just as well—and yet you will find big engines with jacket walls of 1¼-in. cast-iron for many feet in diameter. Think of all the weight that goes with that, and for what? To hold water and transmit an upward tension load from the cylinder head down to the main bearing. Nothing could be more fundamentally wrong. In the first place, as to the material: It is all cast-iron and is always in tension if it is loaded at all. If it were a steam engine there would be an alternate compression and tension; but here it is tension-loaded, and if there is any worse material than cast-iron for carrying a tension load, it is probably cast aluminium. Furthermore, if such a cylinder line barrel is strong enough to resist bursting, it has just twice the factor of safety for the longitudinal tension stress, which means that the double metal of line and jacket is entirely unjustified. The cylinder should be held to the frame at its crank end and the jacket eliminated as a stressed member. There is no reason for carrying a heavy cast-iron wall for a jacket, when ordinary tank steel will do the job just as well and a little bit better. We have oxygen welding apparatus that will enable us to weld the edges of a thin sheet to cast-iron with perfect success and with not much expense.

There is then a necessity for changing the cylinder to take off that unnecessary weight. Do you know that some of these engines of stationary form—the class I am condemning—weigh 600 lb. per horse-power? Think of it! And when these same engines are refined down for ship work without changing the type of structure, just the same typical arrangement, but reducing the bedplate and getting rid of flywheels, they come down to about 150 lb. per horse-power. But there they stick. To go below that it is necessary to change the structural arrangement to conform more and more nearly to the better and more refined class of standard steam practice, and in this country there are excellent models for them, and all that has to be done is to follow them out and keep within the same method of calculating loads and factors of safety—keep the same factors and the result will work just as well as in the steel. That means not only the taking away of this cast jacket and making the cylinder barrel carry the two kinds of stress—the bursting and the longitudinal at the same time, which it is perfectly able to do—but it means also to take this heavy cast-iron frame structure away from the space between the cylinder end and the bedplate and to substitute for it the steel tension rod construction of the torpedo boat or yacht engine—to mention the two most highly-developed forms of that structure. To be sure, that type of engine is not a stiff engine. Certainly the cylinders are going to sway and weave. But what of that? Where did these oil-engine designers get the idea that this thing had to be a stiff structure, like a brick wall? I do not know where, but they got it, and there it sticks.

The most successful engines we have to-day, and the most wonderful machines that we have ever designed, are steam locomotives. When you consider what they have to do and how well they do it, they are truly wonderful. What would happen to a locomotive that was built stiff? And what would happen to the rails on which it runs? You would have neither locomotive nor rails at the end of the first run. The steam engine that gives years and years of service and is regarded as a model of reliability, carrying a ship trip after trip, back and forth across the ocean like a ferryboat—is that a stiff structure? It is not; it weaves and twists, but that does not hurt it. Why, then, should we insist upon the cast-iron stiff structure for oil engines? There is no reason on earth why we should. So I say that we can take the steam-engine structure from bedplate to cylinder and design and apply it to oil engines, selecting dimensions to give similar elastic factors, bearing loads, and so forth, and it should give equal success.

After these two changes it will be time to remove the outside cast wall of the cylinder head. By taking the cast head jacket away from the top of the head we will free the valve housings, the intake and exhaust ports, the housing for spray valve and starting valve. These will then be exposed and the present elaborately-cored casting eliminated. These cored heads are so awful the foundrymen and moulders are not to be blamed for doing with them what they always do when they get into a corner with cores that are too intricate—they knock a piece off; and then we wonder why the head overheats. The designer thought he had provided for water, but the moulder could not get it there, and the designer is responsible for asking a moulder to do what no man could do. In proportion as that casting is made easy to mould, so it will be a good job. By means of the oxygen weld the whole cylinder head top can be left off and the only cores left are the cores for the intake and exhaust, which are easy cores. Then you get a clean casting which can be inspected on both sides and free of bad shrinkage stresses, add a sheet jacket welded around the edges, and you will have a real job.

Just as an indication of what happens when this thing is carried out, even in part, I will tell you that the most highly-developed of these oil engines to-day are the submarine engines. In those engines the heavy cast frame structure in the better of them has been removed, and, as a consequence of the steam-engine practice as to frame structure, those engines, which in the older form of oil-engine structure weighed 150 lb., more or less, to the horse-power, have come down to what? Thirty-five lb. or 40 lb. per horse-power. They still, however, are carrying the cast-iron jacket and a cast-iron roof to the head, so there is room for saving some more without doing any harm whatever.

To conclude, then, with a word or two about the auxiliaries—especially with ships, because you may get a perfectly fine engine, and by wrong kinds of auxiliaries or wrong arrangement of auxiliaries have an awful hard engine-room to work. The tendency for some time has been to regard the engine structure, when it comes to auxiliaries, as a sort of Christmas tree on which you hang anything you want to use. If they decided to put a fire alarm in the engine-room, I have no doubt that they would stick it on the engine somewhere. You find circulating pumps, air compressors, water pumps for circulating water, and oil pumps, in some cases bilge pumps—all hooked on to the main structure of the engine, which, in some cases and quite a number, is 2-cycle, with a row of scavenging cylinders stuck along one side, so that they resemble the old river boat engines. It certainly makes a weird combination, and in the old-day steam-engine practice just that thing was done. They carried feed pumps on the engine, condensers were mounted on the engine, and hot well and circulating pumps likewise. It took us 150 years to get rid of that arrangement, and it is no longer standard practice. The engine structure should be preserved and respected as an engine structure, and not interfered with at all by hanging any kind of trimmings on it that have the slightest possibility of interfering with access to the engine. Doubly so is that true when the auxiliary attached to the engine does not and cannot behave right as attached.

In the latter connection I would call your attention particulary to the circulating pump for water. When the circulating pump for water is driven off the engine, either by its own crank or by rocker and links from other moving parts, then when the engine stops the water stops, and when the engine starts the water starts. That might seem to be a desirable thing at first glance. As a matter of fact, it is positively dangerous, and many cracked cylinders and piston heads can be traced to that cause alone; because, consider the interior of a cylinder when the engine is running at full power, and you will see that there are some hundred pounds of metal very hot—quite hot in proportion as it is thick. Now when that engine is shut down heat is there as insensible heat of the metal, and the jackets are full of water—X lb. of water and Y lb. of hot metal. If the weights and heats involved are figured out you will find in a big engine there is enough heat in the metal to evaporate all the water to steam and you would still have some left to conduct out to more distant parts, which should be cold—parts which are designed to be cold, but which, when hot, crack. Especially is that true when after such a shut-down and a general heating somebody starts the engine and shuts a lot of cold water up against the surface. That condition can be eliminated only by completely independent jacket water circulators separately driven by another engine, which permit the running of the water so long as water comes out from the discharge with any rise in temperature over the intake. In other words, the water should be continued through such an engine until it ceases to become warm, and that may be from 20 minutes to half an hour after the shut-down, depending on the size and style of machine.

A similar discussion could be carried on about other auxiliaries. This question of auxiliary arrangement and starting by an auxiliary engine is just as important for study as the engine itself. There is just as much room for improvement as in the engine structure, as a structure, or the engine parts that are concerned with its functional operation.

Getting back now to the beginning, it must be admitted, and the more you study it the more willing you will be to admit it, that, while we have made very considerable progress with the heavy oil engine, that progress is by no means ended. In fact, we can go much further yet than we have already gone, and we can make the heavy oil engine meet conditions it has heretofore failed to meet.

The Institution of Electrical Engineers.—A.M.I.E.E. Examination.—In view of the practical impossibility while the war continues of holding the A.M.I.E.E. examination and of candidates having the requisite time to prepare for or undergo examination, the Council of the Institution of Electrical Engineers have decided to suspend temporarily the Institution rules in regard to examinations. The greatest care will nevertheless be exercised by the council to ensure that only candidates possessing the qualifications laid down in the Articles in respect of training and experience are admitted to associate membership. Candidates who have been informed that they have been approved for associate membership subject to their passing the examination and who desire their applications to be reconsidered by the council are required to communicate with the Secretary, at No. 1, Albemarle-street, W. 1.

Census of Private Owners' Railway Wagons.—The Board of Trade have made an Order under the Defence of the Realm Regulations providing for a census of all railway wagons not owned by railway companies. The form of return, which has been drawn up with the assistance of the Railway Clearing House, provides for a statement of the size, capacity and description of wagons, the traffic for which they are designed or mainly used, and the station, colliery or works at which they are generally loaded. The obligation to furnish the return is placed upon the person or firm on whose behalf the wagon is running on August 1, 1918, except in the case of wagons hired for less than three months. In the latter case the owner is required to obtain and furnish the particulars. A part of the information now required was obtained some time since by colliery owners' associations, so far as related to the wagons used by collieries. No complete information regarding other railway wagons appears to have been compiled hitherto. The Board of Trade have prepared a list of owners, and forms for the purpose of making the return will be despatched to them. As, however, the return is obligatory, under penalty, owners who do not receive a form before August 1 should apply to the Board of Trade, Statistical Department, 68, Victoria-street London, S.W. 1, for a copy of the form. The return is required to be completed on or before August 14.